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THE SALT REQUIREMENT OF GROWING PIGS

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It is generally agreed that the addition of common salt to the rations of farm animals is good practise. This simple mineral, supplying sodium and chlorine, compensates for a deficiency of these two elements which is likely to occur in rations made up largely on the basis of cereals and cereal by-products. The physiological importance of salt in connection with the stimulation of salivary secretion and digestive processes, as well as its rôle as an appetizer, suggests the importance of studying the effect of eliminating it from the ration of farm animals and of administering it at varying levels. The requirements of the several species of farm animals undoubtedly vary as a result of differences in the arrangements of the digestive apparatus and sources of loss of sodium chloride from the body.

With special reference to the pig, it was shown by Evvard (1) in 1925, that the addition of common salt to a ration of corn balanced with various protein supplements resulted in a marked increase in gain and a lowering of the feed requirement per unit of gain. Evvard's experiments and others of a similar type focussed attention on the special need of the pig for salt and provided a basis for the inclusion of this ingredient in varying amounts in mineral mixtures designed for use in pig feeding. In view of the variation in the sodium chloride content of such mineral mixtures, and a lack of uniformity in connection with recommendations being made with respect to the amount of salt which should be added to pig rations, it was decided to conduct certain experiments in feeding salt to pigs at the University of Alberta. Experiments were carried out during the winter of 1936–37, the summer of 1937 and the winter of 1937–38.

While the procedure in the various trials varied somewhat, the main objective was to note the effect on rate of growth and feed utilization, of adding salt in varying amounts to a standard basal ration. The feeds used were analysed to determine the sodium chloride content so that a calculation could be made of the daily intake as the level of salt in the ration was increased. In view of the possibility that a heavy intake of salt might result in water retention in the body, and thus contribute to a lack of firmness of the carcass or excessive shrink at slaughter, samples of muscle were collected for determination of moisture content. Since the kidney is an important organ from the standpoint of salt elimination from the body of the pig, it was thought that heavy salt feeding might stimulate kidney enlargement and pathologic change in the organ. Kidneys were collected from the pigs in certain of the experiments and were weighed and given gross examination. A periodic check up was made on the water consumption in the various experimental groups.

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PLAN OF THE EXPERIMENTS

The three experiments were conducted on a uniform basis with respect to such matters as number and allotment of pigs in the various groups, standard grain ration and supplemental mixture, method of feeding and general treatment.

The grain mixture was changed when the pigs reached a weight of approximately 110 pounds and consisted of the following:—

	Oats (3CW)	Barley (3CW)	Wheat (5N)
	Parts by weight		
Start of experiments to 110 lbs.	30	50	20
110 lbs. to conclusion of experiments	10	60	30

The supplement fed contained the following ingredients: tankage 55 lbs., linseed oil meal 40 lbs., ground limestone 5 lbs. This supplement was added to the grain at the rate of 10 lbs. to 90 lbs. of grain during the entire period of the experiment.

Cod liver oil of good poultry grade but not carrying a guarantee regarding vitamin content was fed in all lots at the rate of 1 lb. added to each 100 lbs. of the grain and supplement mixture until the pigs reached a weight of approximately 110 lbs.

The pigs were watered three times daily and were allowed sufficient to satisfy their requirements. In the winter experiments the water was warmed slightly.

The grain was fed from self feeders in all experiments.

The salt fed was the coarse granulated sample ordinarily supplied to livestock.

The pigs were housed in a shed type of piggery, the walls and ceilings of which were packed with shavings. Pens were 10 feet × 12 feet in size with concrete floors and wooden sleeping platforms, and the pigs were confined to these pens during the period of the experiments.

Straw was used for bedding.

EXPERIMENT I (WINTER 1936-37)

In Experiment I, five groups of 7 pigs were included. Lot I did not receive any salt in addition to that carried in the standard grain and supplement mixture. In the other four lots salt was added at the rates of 0.5, 1.0, 2.0 and 3.0 lbs. to each 100 lbs. of the feed mixture. The groups were:—

Lot I— Grain mixture—Supplement—No salt
Lot II— Grain mixture—Supplement—0.5% salt
Lot III— Grain mixture—Supplement—1.0% salt
Lot IV— Grain mixture—Supplement—2.0% salt
Lot V— Grain mixture—Supplement—3.0% salt

The analysis of the various ingredients of the grain and supplement mixture is shown in Table 1.

TABLE 1.—CHEMICAL ANALYSIS OF THE RATION—EXPERIMENT I

—	Dry matter	Crude protein	NaCl
Oats	88.33	10.03	.0094
Barley	88.57	13.32	.0033
Wheat	88.28	12.19	.0058
Linseed oil meal	92.22	36.90	.0290
Tankage	92.61	57.08	1.2080

Based upon this analysis and the addition of common salt in the amounts indicated, the average daily intake of sodium chloride in the various groups was calculated as shown in Table 2.

TABLE 2.—AVERAGE DAILY INTAKE OF NaCl

—	Daily food intake (lbs.)	Daily NaCl intake (gms.)
Lot I	4.90	1.83
Lot II	5.47	14.30
Lot III	5.20	25.00
Lot IV	5.96	55.20
Lot V	5.53	74.60

The addition of common salt to the standard ration provided for a wide range in daily intake of sodium chloride in the various lots. The minimum requirement of the pig for sodium chloride could be determined on the basis of daily retention of chlorine but data of this type appear to be very meagre. According to German investigations (2), four feeding and metabolism experiments indicated that pigs fed a well balanced ration retained in the body 0.81 grams of chlorine for each 1 pound increase in live weight. If chlorine was retained mainly as sodium chloride, the minimum daily requirement, if complete absorption took place, would be approximately 1.33 grams for a pig gaining at the rate of 1 pound daily. On the basis of this calculation it would appear that the pigs in Lot I were receiving sodium chloride in an amount close to the normal requirement and in the other lots the intake was probably considerably in excess of the actual needs of the animals.

The results of Experiment 1 are indicated in Table 3.

TABLE 3.—RESULTS OF EXPERIMENT I (WINTER 1936–37)

——	Lot I Standard ration No. salt	Lot II Standard ration 0.5% salt	Lot III Standard ration 1% salt	Lot IV Standard ration 2% salt	Lot V Standard ration 3% salt
No. of pigs in lot	7	7	7	7	7
Av. initial wt. (lbs.)	50.76	50.3	49.47	51.49	51.04
Av. final wt.	201.14	215.7	210.14	214.0	213.0
Total gain	1115.7	1157.9	1124.7	1137.6	1133.7
Av. daily gain	1.29	1.35	1.31	1.35	1.31
Av. daily feed consumed	4.90	5.47	5.20	5.96	5.53
Total feed required for 100 lbs. gain	377.93	404.75	396.12	439.71	419.75
Av. daily consumption of water (period of Jan. 8 to March 6)	10.6	12.2	12.7	16.9	18.7
Av. wt. of kidneys (grams)	123.7	119.9	121.9	126.4	137.4
Av. percentage moisture in muscle	74.0	74.3	76.5	72.4	73.9

The rate of growth as shown in Table 3 and in Figure 1 is remarkably uniform in all groups in this experiment, and a difference as small as 0.06 lb. per day between the lowest and the highest gaining group can scarcely be regarded as significant.

While the addition of salt to the ration resulted in some increase in daily feed consumption, this did not give rise to a lowering of the feed requirement per unit of gain. The most efficient utilization of feed was obtained in Lot I where salt was not added to the ration. It is apparent that the standard ration contained sufficient salt for normal functioning under the conditions of this experiment. What would appear to be an excess of sodium chloride in the other groups led to less efficient utilization of the feed.

The feeding of salt led to an increase in water consumption, the difference being most marked in the case of Lots IV and V receiving 2% and 3% of salt respectively. The average daily consumption in Lot I (no salt) was 10.6 lbs. daily during the check period from January 8th to March 6th, and 18.7 in Lot V (3% salt). The increased use of water was of course accompanied by a marked increase in urination which made it difficult to keep the pens in a dry condition.

Kidney weights do not show any consistent trend toward enlargment of the kidney as the intake of salt increased. While the heaviest kidney weights were secured in the lot fed 3% salt, in view of the wide range of weight of individual kidneys in the various groups, it is felt that no significance can be attached to the differences. Gross examination of the kidneys indicated a normal condition in all cases.

The percentage of moisture in the tenderloin muscle did not appear to show any relationship to the amount of salt fed to the pigs. The average percentage of moisture in the tenderloins from the pigs fed without the addition of salt was 74.0 (range 70.7–76.1) and in those from the pigs fed 3% salt it was 73.9 (range 70.5–77.04). It would appear that when up to 3% of salt was added to the ration and provision made for an adequate water allowance, the salt was excreted from the body without any tendency toward an increase in the water content of the tissues.

EXPERIMENT II (SUMMER 1937)

In the second experiment conducted during the summer of 1937, some changes were made in the arrangement of the groups as compared with Experiment I. In view of the apparent failure of salt feeding to show any improvement in rate of growth and economy of feed utilization, and the comparatively high salt content of the tankage fed, it was decided to place three groups of pigs on the grain ration without the protein supplement and compare them with three groups fed the supplement as in the previous experiment. In the three non-supplemented groups, 0.5% of ground limestone was fed in order to compensate for the calcium supplied in the supplement. This arrangement provided a basis for measuring the value of salt feeding when tankage is not fed as is so often the case under farm conditions. In both series one group did not receive salt, one was fed salt at the rate of 0.5% of the ration and one at the 3% level.

Before presenting the results of this experiment it may be mentioned that the pigs which did not receive the protein supplement became very unthrifty as the experiment progressed, although the two groups receiving salt were definitely better in appearance than the group deprived of salt. By September 12th, 112 days after the commencement of the trial, it was apparent that while the salt fed groups showed fewer signs of malnutrition than the group deprived of salt, the three groups of pigs were suffering from protein deficiency. At this stage the pigs in Lot I (no salt) were drinking urine and showing marked symptoms of salt craving. The condition of their hair and skin was bad. On September 12th the protein supplement was added to the grain ration of these three lots at the rate of 10%. In view of this change in the feeding programme, the table of results will be presented to show the performance during both periods, together with a summary for the entire period of the experiment.

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TABLE 4.—RESULTS OF EXPERIMENT II

—	Lot I No salt No supp. 1st period	Lot II Salt 0.5% No. supp. 1st period	Lot III Salt 3% No supp. 1st period	Lot IV No salt Supp.	Lot V 0.5% salt Supp.	Lot VI 3% salt Supp.
1st Period—Lots 1, 2, 3—May 21 to Sept. 10. Lots 4, 5, 6—May 27 to Aug. 13.						
No. of pigs in lot	7	7	7	7	7	7
No. of days in period	112	112	112	84	84	84
Av. initial wt. (lbs.)	35.5	34.5	35.0	33.7	35.1	34.0
Av. final wt.	77.2	91.7	95.7	108.7	112.1	120.3
Av. daily gain	.37	.51	.54	.89	.92	1.03
Av. daily feed consumed	2.43	2.70	2.90	3.23	3.23	3.80
Feed required for 100 lbs. gain	652.40	527.40	532.94	362.1	352.33	369.53
2nd Period (Supplement added to Lots 1, 2 and 3)						
No. of days in period	79	68	66	59	58	48
Av. initial wt.	77.2	91.7	95.7	108.7	112.1	120.3
Av. final wt.	209.3	217.1	208.0	209.1	206.6	206.7
Av. daily gain	1.68	1.84	1.70	1.71	1.64	1.80
Av. daily feed consumed	5.90	6.42	6.37	6.50	6.03	7.22
Feed required for 100 lbs. gain	350.8	347.84	374.68	380.10	368.84	401.0
Full Period of Experiment						
No. of days on experiment	191	180	178	143	142	132
Av. daily gain	.91	1.01	.97	1.23	1.21	1.31
Av. daily feed consumed	3.86	4.10	4.18	4.58	4.37	5.04
Feed required for 100 lbs. gain	423.1	404.10	430.2	372.4	361.42	385.27
Av. dressing percentage	75.6	74.7	75.6	75.2	78.4	75.7
Av. wt. of kidney (grams)	—	—	—	130	122	133
Av. daily water consumption (Sept. 10) per 100 lbs. live weight	6.00	4.4	5.3	10.1	11.6	17.5

Reference to Table 4 will show that there was improvement in appetite, an increase in the rate of growth and greater efficiency in the utilization of feed as a result of salt feeding during the first period of the experiment in Lots 2 and 3. Feeding the salt at the 0.5% level proved as effective as feeding at the rate of 3% of the grain ration. The rate of growth in Lot 1 together with the symptoms of depraved appetite which developed in the pigs in this group, would indicate that the non-supplemented ration was deficient in sodium chloride. The daily intake during the period in question would not have been much over 0.06 grams daily.

The trend shown in rate of gains during the first period in the three lots fed the protein supplement suggests that some benefit was derived from salt feeding although in these groups economy of production is not in keeping with the growth rate.

The remarkable improvement in the condition of the pigs in Lots 1, 2 and 3 following the addition of the protein supplement is indicated by the rate of gain shown in Table 4 (second period) and by the curves in Figure 1. Lack of protein appeared to be more of a limiting factor in connection with growth than a lack of salt.

An analysis of the results for the full period of the experiment suggests that depriving the pigs of salt during the period when the ration was not supplemented resulted in a lowering of the rate of gain but did not significantly affect the final outcome with respect to the utilization of feed. A comparison of the rate of gain in the three groups which received the supplement during both periods indicates very marginal differences in rate of growth and lack of a consistent trend with respect to feed required for 100 lbs. gain in weight. As in the first experiment, the least economical production was secured when 3% of salt was added to the ration.

A check on the water consumption of the pigs in the various lots shows that there is no marked increase in the demand for water when salt is added at the 0.5% level, but when salt is added at 3% the thirst increases very definitely.

Data secured at the time of slaughter shows that the feeding of salt at a high level did not have any effect on dressing percentage.

The average weights of single kidneys from the pigs in lots 4, 5 and 6 do not indicate that salt feeding exerted any influence on the size of these organs.

EXPERIMENT III (WINTER 1937-38)

In connection with the third experiment, three groups of pigs were arranged to secure a check on the addition of salt to the supplemented grain ration at two levels, namely, 0.5% and 3%.

The various ingredients of the ration were analysed with the following result:—

——	Oats	Barley	Wheat	Linseed oil meal	Tankage
Crude protein, %	10.41	11.64	12.28	39.66	54.82
Ash, %	2.78	2.20	1.66	4.70	19.60
NaCl, %	.0065	.005	.0036	.0027	.693

Calculating from these analyses, and on the basis of average daily feed consumption during the period of the experiment, the approximate average daily intake of sodium chloride in the three groups is shown in Table 5.

TABLE 5.—AVERAGE DAILY INTAKE OF NaCl

—	Av. daily feed consumed	Av. daily intake NaCl
	lbs.	grams
Lot I (No salt)	5.36	1.7
Lot II (0.5% NaCl)	5.52	15.0
Lot III (3% NaCl)	5.33	71.5

It will be noted from Table 5 that the standard ration used, without the addition of common salt, supplied approximately 1.7 grams daily of sodium chloride as compared with the calculated minimum requirement of 1.33 grams for a pig increasing in weight at the rate of 1 lb. per day.

The results of Experiment III are shown in Table 6.

TABLE 6.—RESULTS OF EXPERIMENT III

	Lot I Standard ration No salt	Lot II Standard ration 0.5% salt	Lot III Standard ration 3% salt
No. of pigs in lot	7	7	7
Av. no. days on experiment	130	126	137
Av. initial wt.	36.3	37.2	36.1
Av. final wt.	208.3	203.6	202.3
Av. daily gain	1.32	1.32	1.21
Av. daily feed consumed	5.36	5.52	5.33
Feed required for 100 lbs. gain	403.2	413.4	424.3
Average dressing percentage	74.0	75.4	74.3
Average daily water consumption per 100 lbs. live weight (April 5)	9.1	9.7	13.0

In this experiment the feeding of salt did not result in any increase in the rate of growth. In the case of the group fed 3% salt the average daily gains were lowered by 8%.

When the average daily gain in the three groups is considered in conjunction with the progressive increase in the feed requirement for 100 lbs. gain, it would appear that the addition of salt to the ration under the conditions of this experiment failed to make any contribution to improvement in physiology but rather exerted a depressing effect. It will be noted from the growth curve in Figure 1 that the pigs in Lot III (3% salt) lagged somewhat in rate of growth during the entire period of the experiment.

Dressing percentages do not appear to be out of line with normal variations, and the fact that Lots 1 and 3 are so close in this respect would indicate that salt feeding did not exert any significant influence on carcass yield.

The check on water consumption in this experiment again indicates the increased demand for water when heavy salt feeding is practised.

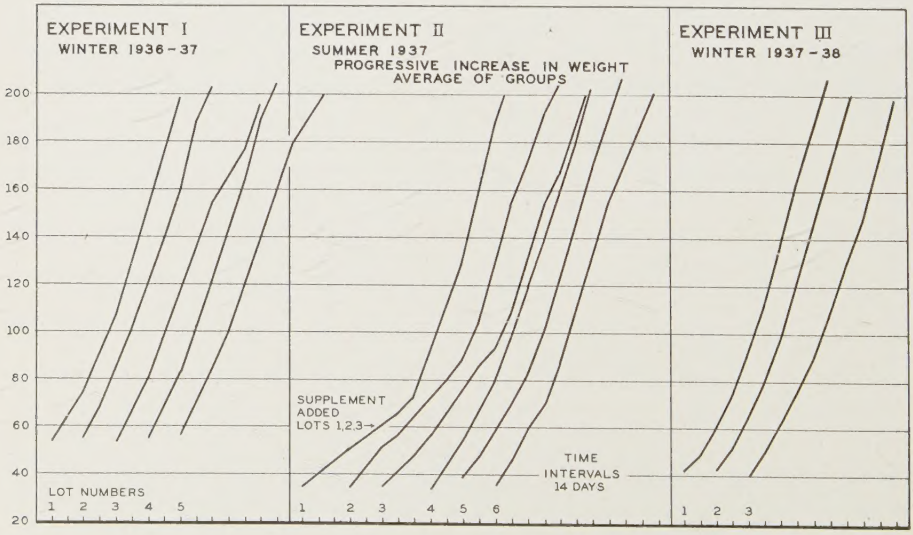

FIGURE 1.

SUMMARY

A review of the three experiments will show that there was some inconsistency in the results from the standpoint of the influence of salt feeding on rate of growth. The only instance where salt feeding gave rise to what would seem to be a significant increase in rate of gains was in the first period of Experiment II where in Lots 2 and 3 the gains were proportionally much better than in Lot 1 where no salt was fed. As was noted previously, however, with the addition of the protein supplement the difference became less noticeable. A comparison which was made uniformly in the three experiments was that of the standard ration without salt and the same ration with salt added at a low level of 0.5% and a comparatively high level of 3%. An analysis of the average daily gains in these three groups in the three experiments shows the following:—

——	No. of pigs	Mean daily gain	Probable error	Coefficient of variability
Lot I— No salt	21	1.294	.022	11.43
Lot II— 0.5% salt	21	1.297	.021	10.84
Lot III—3.0% salt	21	1.287	.016	8.29

Since a difference of 0.095 lbs. in daily gains between Lots 1 and 2 and of 0.086 between Lots 1 and 3 is necessary before it could be regarded as significant, it is clear that the feeding of salt did not exert any effect on the rate of growth when 10% of a supplement containing 55% of tankage was fed.

Considering the same groups from the standpoint of feed utilization, an average of the three experiments gives the following result:—

——	No. of pigs	Av. daily feed consumed	Feed required for 100 lbs. gain
Lot I— No salt	21	4.94	384.5
Lot II— 0.5% salt	21	5.11	393.2
Lot III—3% salt	21	5.29	409.8

The addition of salt to the ration appeared to lead to a slightly larger consumption of feed daily, but this was not accompanied by more efficient utilization of the feed as the feed requirement for 100 lbs. gain increases with the feeding of additional salt. It may be well to refer again at this point to the influence of adding salt under the condition of extreme salt deficiency which existed in Lot I in the first period of Experiment II. In that case when it was calculated that the daily intake of salt was around 0.06 grams daily, the addition of salt made for definite improvement. This suggests that the sodium chloride content of the basal ration must be considered in making recommendations regarding the addition of salt and in estimating the results to be expected from salt feeding. Under the

condition of salt starvation which pertained in Lot I, the addition of 0.5 lbs. of salt in each 100 lbs. of the grain mixture gave as good results as the addition of 3 lbs.

While the moisture content of the lean meat was not determined in all of the experiments the findings in this connection in the first trial did not suggest any relationship between salt feeding and water retention in the body tissues. Kidney function did not appear to be disturbed as differences in kidney weights between groups were small as compared with normal variation within groups and gross examination did not show any difference in the appearance of these organs.

CONCLUSIONS

1. The addition of common salt to a ration consisting of a cereal mixture, supplemented with tankage, linseed oil meal and ground limestone, did not result in a significant increase in the rate of gain.

2. When the same grain ration was not supplemented, pigs developed symptoms of "salt craving" and became very unthrifty in appearance. The addition of salt to the ration under such conditions led to improvement in the rate of growth and evidence of better general thrift in the pigs, indicating that a deficiency of common salt may be a limiting factor in economy of swine production in certain cases.

3. When the supplemented ration was fed the efficiency of feed utilization was not improved by the addition of salt, but when the grain ration alone was fed the feed requirement per unit of gain was lowered by adding salt to the grain mixture.

4. Based upon a chemical analysis of the various ingredients of the rations, it is calculated that the pigs fed the non-supplemented ration were supplied with approximately 0.06 grams of sodium chloride daily, and those receiving the supplemented ration, 1.7 grams daily. Adding 0.5% of salt to the supplemented ration increased the average daily intake of sodium chloride to approximately 14.6 grams daily, while the addition of 3% of salt increased the average daily intake to approximately 73 grams.

5. The estimated daily requirement of sodium chloride for a pig increasing in weight at the rate of 1 lb. per day, based on chlorine retention, would seem to be approximately 1.33 grams. In view of the fact that pigs on an intake of 1.7 grams daily, gave as satisfactory performance as those receiving larger amounts, it would appear that the actual salt requirement of the pig is comparatively small and in the region of the calculated quota.

6. The results suggest that in planning for the addition of salt to swine rations and in compounding mineral mixtures, the salt content of supplements being included in the ration should be taken into consideration.

7. Where the necessity for additional sodium chloride in the ration is indicated, it would appear that adding 0.5% of salt should meet all requirements. The experiments reviewed do not present any evidence in favour of administering larger amounts.

8. Increasing the amount of salt to 3% of the ration did not give rise to excessive retention of moisture in muscle samples and did not exert any significant effect on dressing percentage.

9. The additional strain on kidney function due to heavy salt feeding did not cause any increase in size of kidneys, which could be regarded as significant, nor give rise to any change in the gross appearance of these organs.

10. Feeding salt up to 3% of the ration led to a marked increase in water consumption and excessive urination.

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STANDARDIZATION OF RAPID SOIL TESTING TECHNIQUE[a]

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INTRODUCTION

Recognition of the value of rapid soil tests in supplementing field observations in the diagnosis of soil fertility problems has resulted in an ever-increasing number of soil samples being received at this laboratory for routine examination. The necessity of the rapid handling of these samples with the maximum economy of labour has led to the adoption during the past year of various mechanical devices designed not only to save time, but to place the work on such a systematic basis that errors resulting from the personal factor are largely eliminated. While no claim can be made to the originality of many of the ideas incorporated, it is felt that the application of certain equipment to the work in question is unique, and in any event that a description of the general set-up may be of value to others similarly engaged.

PREPARATION OF SAMPLES

All soil samples are prepared for analysis in a room reserved for this step of the work, as the fine dust resulting from the crushing and screening operations is objectionable in the laboratory. The majority of the soils received for routine examination are too moist for immediate preparation, necessitating their transferrence to shallow trays for air-drying. These trays are of galvanized iron, 8″ × 12″ and 2″ deep. To save space, racks have been provided by means of which about 100 samples may be dried at one time. The arrangement may be noted in the background of Figure 1.

A pulverizer such as that described by Green (1) has proved very satisfactory for reducing the soil to a suitable degree of fineness. In this connection, mention might be made of certain improved features of the machine which have been found to be desirable. A repulsion-induction type motor, $\frac{1}{6}$ or $\frac{1}{4}$ H.P., is preferable to the split phase type in that it will start under load without danger of burning a fuse. Where large numbers of samples must be handled, the extra cost of this heavy-duty motor is justified. It should be of an enclosed type, such as a late model "Century", because of the dust factor. It was found that an enclosed model may be mounted below the pulverizer without undue interference by dust, but because of the downward pull of the belt, the heavy flywheel should be supported by separate wooden bearings. This feature may be noted in Figure 1. Power is transmitted to the upper rollers by a rubber coupling connecting the flywheel shaft with the extended roller shaft. A chain-and-sprocket type of drive between the upper and lower rollers has been substituted for the belt drive because it overcomes slipping under heavy load. The sprockets, which are obtainable at any bicycle repair shop,

[a] An address delivered before the Soils Group of the C.S.T.A. at the Nineteenth Annual Meeting of the Canadian Society of Technical Agriculturists at Vancouver, B.C., June 19 to 22, 1939.
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[2] Soil Analyst, Department of Chemistry, Ontario Agricultural College.
[3] The sign ″ refers throughout this paper to the unit of linear measurement—inch

should be welded to the shafts. While this pulverizer will handle the great majority of soils quite satisfactorily, an occasional sample may be of such a nature that it resists further reduction even when passed through the machine repeatedly. Such samples must be completed by rolling on an iron board. The soil before analysis must pass through a 2 mm. screen. After mixing, a portion of each sample is transferred to a wide-mouthed glass jar and taken to the laboratory.

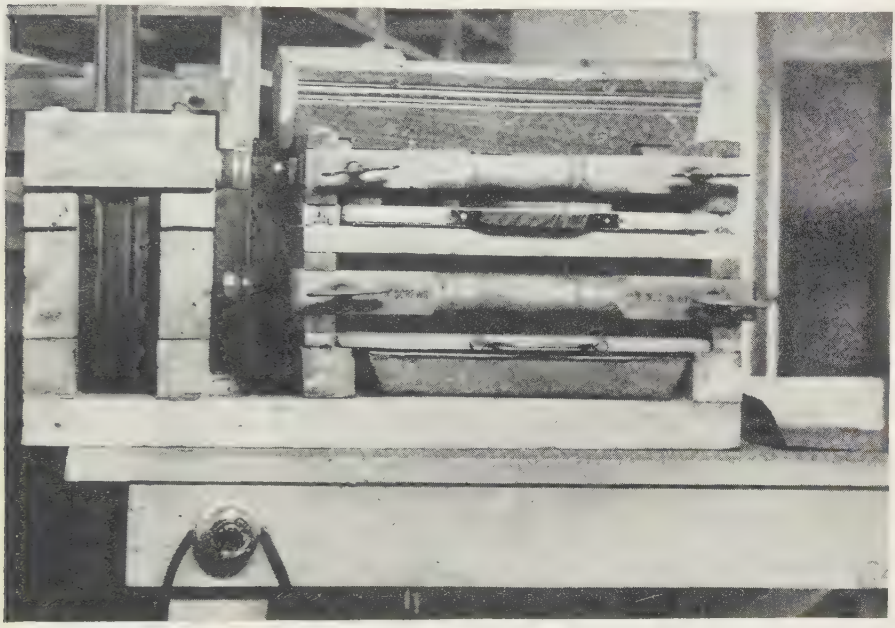


FIGURE 1. Soil pulverizer, showing supported flywheel and chain-and-sprocket drive, with drying racks in background.

EXTRACTION METHODS

At this laboratory routine examination of soil samples commonly involves three separate extractions. The Spurway method (7) is employed in every case for the determination of nitrate nitrogen, water soluble calcium and magnesium, and, in the case of those soils which are thought to be very high in soluble nutrients, for water-soluble phosphorus and potassium. Except for these latter soils, each sample is subjected also to the Modified Thornton test for phosphorus (6) and the Thornton test for potassium (8). It will be recalled that the Spurway test involves shaking $\frac{1}{2}$ teaspoonful of soil with 13 cc. of dilute acetic acid for one minute, while the phosphorus test is made by shaking $\frac{1}{2}$ teaspoonful of soil with 10 cc. of .05N HCl, and the potassium test by shaking 1 teaspoonful of soil with 10 cc. of sodium cobalti-nitrite solution for the same length of time. Carried out by hand, these extracting operations are tedious and time-consuming, and in the hands of different operators, the agitation is not always uniform. Prompted by these considerations, a shaking machine has recently been devised by

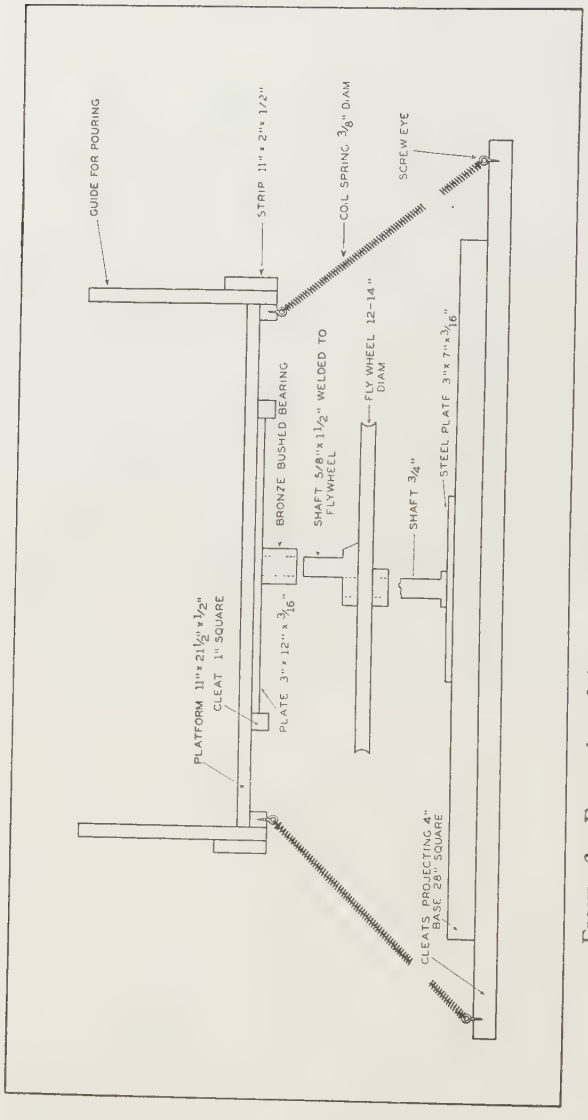

GUIDE FOR POURING
STRIP 11" x 2" x 1/2"
COIL SPRING 3/8" DIAM
SCREW EYE
BRONZE BUSHED BEARING
SHAFT 5/8" x 11/2" WELDED TO FLYWHEEL
FLY WHEEL 12-14" DIAM
SHAFT 3/4"
STEEL PLATE 3" x 7" x 3/16"
PLATFORM 11" x 21 1/2" x 1/2"
CLEAT 1" SQUARE
PLATE 3" x 12" x 3/16"
CLEATS PROJECTING 4" BASE 28" SQUARE

FIGURE 2. Front view of shaker, showing the detail of flywheel and bearings.

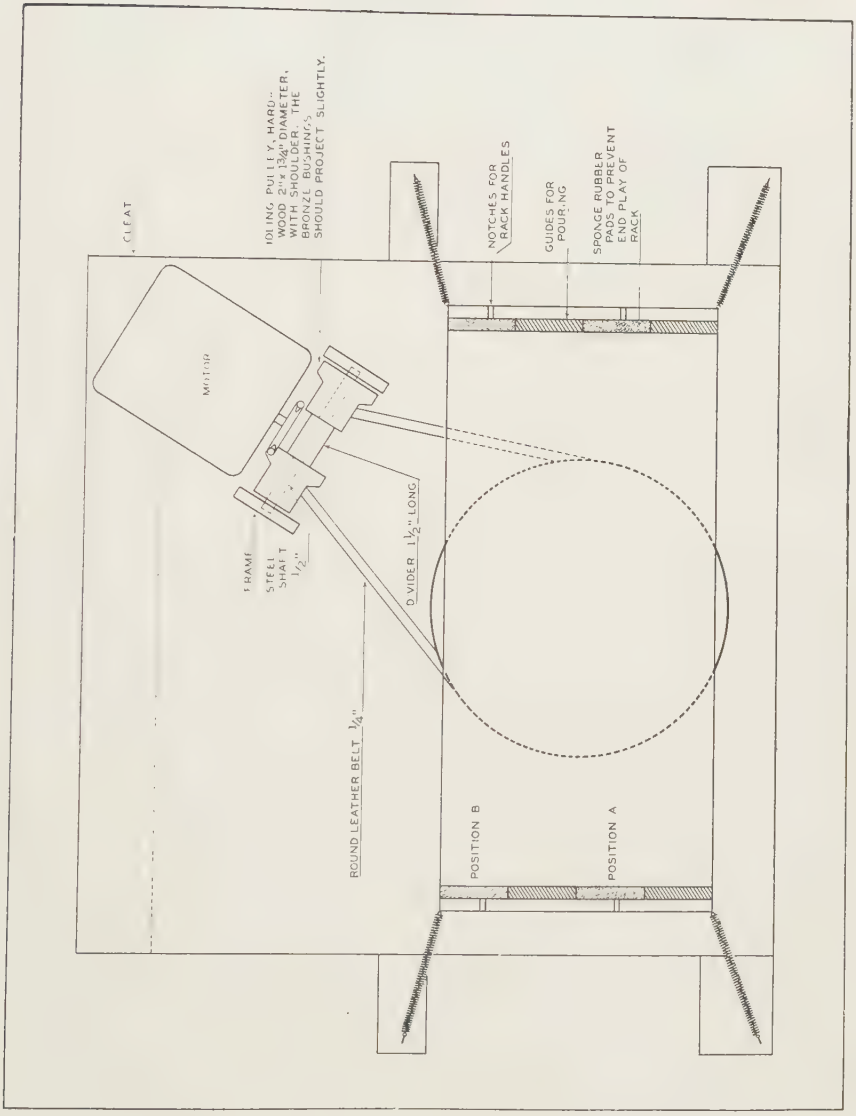

CLEAT
IDLING PULLEY, HARD-WOOD 2" x 13/4" DIAMETER, WITH SHOULDER. THE BRONZE BUSHINGS SHOULD PROJECT SLIGHTLY.
NOTCHES FOR RACK HANDLES
GUIDES FOR POURING
SPONGE RUBBER PADS TO PREVENT END PLAY OF RACK
MOTOR
FRAME
STEEL SHAFT 1/2"
DIVIDER 1 1/2" LONG
ROUND LEATHER BELT 1/4"
POSITION B
POSITION A

FIGURE 3. Top view of shaker, showing detail of motor mounting.

means of which the three extractions mentioned may be performed in the same standardized glassware. By using this equipment, considerable time is saved, the whole operation is standardized, and much tedious hand labour is eliminated.

DESCRIPTION OF SHAKER

Although several types of shaking apparatus are listed in the laboratory equipment catalogues, none, to the authors' knowledge, are satisfactory for this work. The general pattern of the shaker described has been taken from one used for some time in the Soils Laboratory of this Department for the extraction involved in the $KHSO_4$ method (4) for readily soluble phosphorus, as well as for the precipitation of ammonium phosphomolybdate in the determination of P_2O_5 by the Official Volumetric method of the A.O.A.C. (5). This apparatus consists essentially of a platform rotated by a suitable mechanism in such a manner that a swirling motion is imparted to the contents of flasks or beakers placed thereon. The design of the activating mechanism is not that of the authors, but is believed to have been worked out originally at the Agricultural Experiment Station at Knoxville, Tennessee, U.S.A. Only slight changes in the size and design of the base and rotating platform of this shaker were necessary to adapt it to the rapid testing work. Although full details and specifications are given in Figures 2, 3, and 4, a brief description may assist in the interpretation of the diagrams.

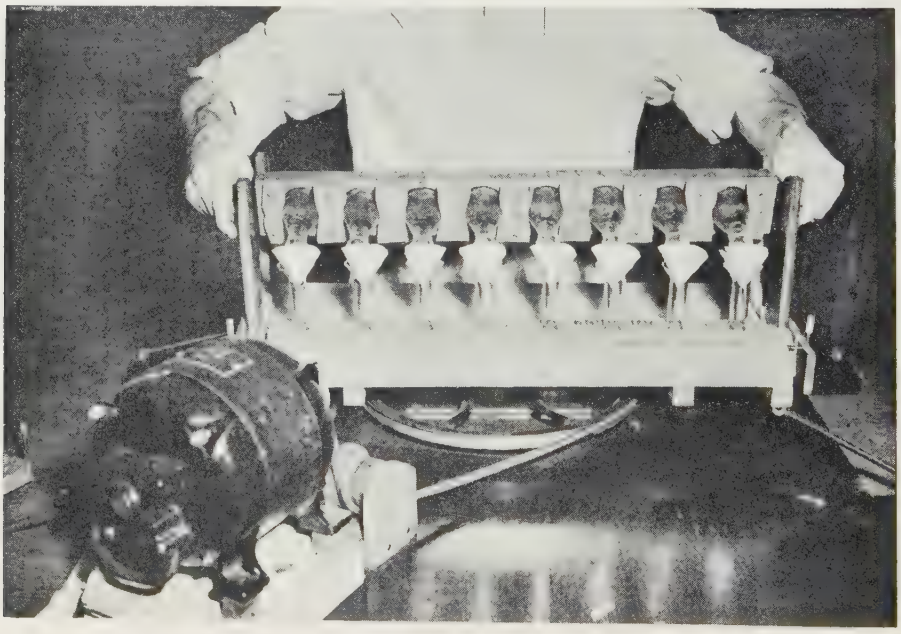


FIGURE 4. Shaking apparatus, showing racks and method of filtering.

Since welding and machine work are involved, the services of a mechanic are required for the constructions of the main mechanism. The essential feature of this is the flywheel, 12 to 14 inches in diameter. The

large grooved treadle wheel of a discarded sewing machine is quite suitable. This is mounted horizontally on a shaft welded to a steel plate, $3'' \times 7''$. The plate is secured by screws to a wooden base $28''$ square, constructed of inch material and held together by three 1-inch cleats. It will be noticed in Figure 3 that two of these cleats extend $4''$ on either side in order that the platform springs may be attached to them. To the flywheel is welded a short steel shaft, about $\frac{5}{8}''$ in diameter, parallel to the bearing and $\frac{3}{4}''$ off-centre. The platform bearing, which may be turned from a short length of steel shafting, is mounted on the shaft projecting upward from the flywheel. To the upper end of the bearing, which should be bronze-bushed, is welded a steel plate, $3'' \times 12''$. The rotating platform, $11'' \times 21\frac{1}{2}''$, which is attached to the plate, may be of $\frac{1}{2}''$ material but should be firmly secured by four 1-inch cleats as shown in Figure 2. Four coil springs, most easily obtained by cutting those used for closing screen doors, are attached by screw eyes to each corner of the platform and extend down to the projecting cleats of the base. Thus, when the flywheel is rotated, the platform, without revolving, describes a circle of $\frac{3}{4}''$ radius. Power is supplied by a $\frac{1}{4}$ H.P. split-phase motor which should be mounted at one corner of the base at such a height that the drive pulley clears the idling pulleys. The latter may be of hardwood but should be bronze-bushed. Their dimensions and manner of mounting are most easily understood by a study of Figure 3. Power is transmitted to the flywheel, which should turn at about 175 r.p.m., by a $\frac{1}{4}''$ round leather belt.

EXTRACTING EQUIPMENT AND PROCEDURE

The extraction is carried out in 50 m.l. Pyrex Erlenmeyer flasks, and the filtrate is received in special funnel tubes of about 15 m.l. capacity. The latter, graduated at 5 m.l., are manufactured by Wiley Ross Inc., of Vineland, New Jersey. For this work the 10 and 13 m.l. mark must be etched on by the user. Two types of rack have been designed, one to hold the Pyrex flasks, the other for the funnel tubes. Both racks are of the same dimensions, $21\frac{3}{8}''$ long, $2\frac{5}{8}''$ wide and $\frac{3}{4}''$ in depth, and hold 8 tubes or flasks. The diameter, depth and spacing of the openings are given in Figure 9. What is believed to be a unique feature is the fact that sponge rubber pads are used to retain the glassware in the racks. These were cut from rubber kneeling pads commonly sold at all hardware stores. By means of the arrangement of the sponge rubber pieces shown in detail in Figure 9, the flasks and tubes may be very easily removed from the racks, yet are held firmly enough that shaking or inverting does not dislodge them. The extraction is carried out as follows:—

1. A measured amount of air-dry soil ($\frac{1}{2}$ or 1 teaspoonful) is placed in each of the 8 flasks held in a rack which is then placed in position A (see Figure 3) on the shaker platform.

2. The funnel tubes, also in a rack, are filled to the mark with extracting solution. This is most easily accomplished by means of a siphon tube with pinch-cock leading from the supply bottle.

3. With the aid of the guides shown in detail in Figure 5 the contents of the 8 tubes are poured simultaneously into the flasks containing the soil, which are rotated for one minute.

4. Meanwhile filter papers, "square-folded," are placed in the funnel tubes and at the end of the shaking period this rack is placed in position B.

5. With the aid of the second set of guides the contents of the flasks are poured into the filter papers in the tubes. When the required amount of filtrate has been obtained, the filter papers containing the soil residues are removed and the tests are completed.

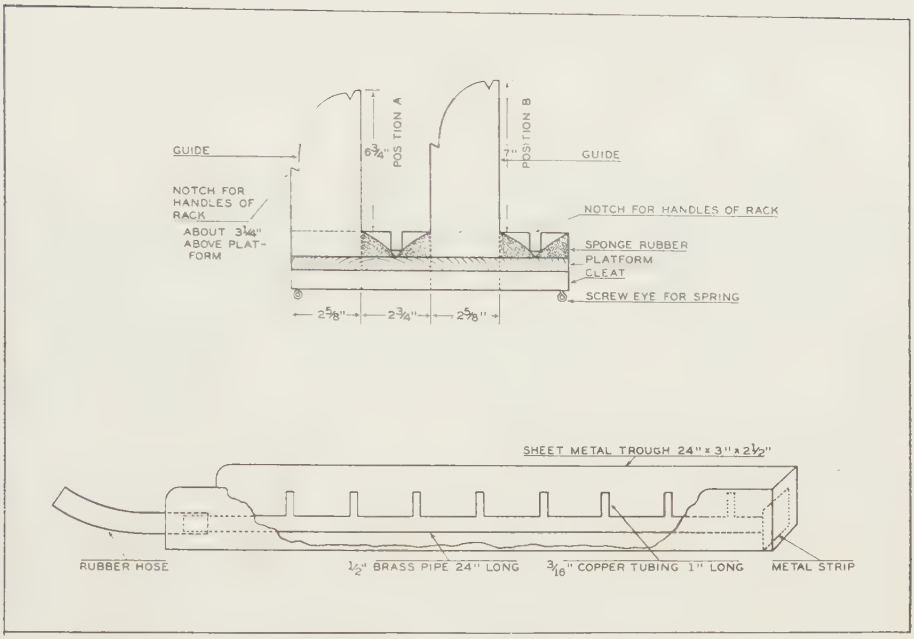
The use of the device shown in Figure 6 makes it unnecessary to remove the glassware from the racks for washing. However, it has been the practice in this laboratory to remove the glassware at the close of the day's work so that the outside of the flasks and tubes may be thoroughly washed. The washing device mentioned consists simply of a length of $\frac{1}{2}''$ brass pipe closed at one end by a flat strip of metal which serves to hold it in the proper position. The upper surface is drilled at $2\frac{1}{2}''$ intervals (corresponding to the spacing of the flasks and tubes) to receive $1''$ lengths of $\frac{3}{16}''$ copper tubing which are secured by soldering. This series of jets is placed in a galvanized iron trough, $3'' \times 3\frac{1}{2}''$, which drains into the sink, and the open end of the large tube is connected to the water supply by a rubber hose. The racks of glassware are first washed with tap-water by inverting over the jets, then rinsed with distilled water, which is conveniently held in a large container placed on a high shelf over the sink. By the use of three sets of racks sufficient time is allowed for drying even when samples are being handled continuously.

READING THE TESTS

The technique involved in the colorimetric or turbidimetric procedures by means of which the ratings are established in rapid soil testing is naturally of considerable importance because of its effect upon the accuracy of the results. A brief description will be given, therefore, of some of the steps which have been taken to eliminate errors in this final stage of the work.

The Spurway (7) system is reasonably simple, and with ordinary precautions the various colours may be developed and compared quite accurately by an operator with a little experience. Except in the case of the potash test the colours may be matched with the colour-charts in the bulletin, under any good source of light. It has been found, however, that to read this test correctly, the unknown should be matched against temporary standards prepared from standard potassium solutions.

The Thornton potash test (8) is completed by the addition of isopropyl alcohol to the soil extract. The speed and manner of mixing these reagents are important in that they influence the degree of turbidity. In the hands of various operators the same results are not always obtained, so in order to standardize this step a mixing device has been developed (Figure 8). This was adapted, with change in design for the work at hand, from the rotator described by Hance (2). It consists of an arm revolving in the horizontal plane, driven by an enclosed chain and sprocket. To each end, at $4\frac{1}{4}''$ from the centre, is attached a vertical hinged steel rod, $9''$ by $\frac{1}{4}''$. A removable wooden rotor (Figure 7), holding 4 funnel tubes, slips on the upper end of each rod. Springs on the arm hold the rotor against a circular track, actually part of the frame. As the arm revolves, the rotors are



Top.—FIGURE 5. Detail of guides and retaining pads (inside view).
Bottom.—FIGURE 6. Washing apparatus.

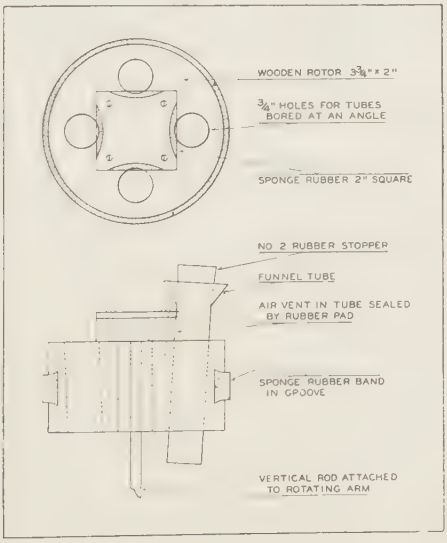

WOODEN ROTOR 3¾" x 2"
⅜" HOLES FOR TUBES BORED AT AN ANGLE
SPONGE RUBBER 2" SQUARE
NO 2 RUBBER STOPPER
FUNNEL TUBE
AIR VENT IN TUBE SEALED BY RUBBER PAD
SPONGE RUBBER BAND IN GROOVE
VERTICAL ROD ATTACHED TO ROTATING ARM

FIGURE 7. Detail of rotor for potash mixer.

subjected to both a revolving and rotating motion which mixes the potash-test solutions in the proper manner. One minute is required for mixing 8 extracts. These potassium tests to date have always been read with the aid of the lined charts supplied in Thornton's Bulletin (8) but attempts are being made to increase the ease of reading by the use of the illuminator described in the next paragraph.

FIGURE 8. Hand-operated mixer for potash test.

In the Modified phosphorus test, the blue colour developed may be read with the aid of colour charts, provided a satisfactory source of light is always available. For accurate results, however, it is desirable that permanent standards be used in conjunction with an illuminator. This may consist of an enclosed box with white-painted interior, indirectly lighted by "Day-light" bulbs placed at the front. The light is diffused through a ground glass screen, before which the unknown solutions are compared with the standards. The phosphorus standards in use at present are prepared from methylene blue (3) with the addition of small amounts of methyl red, and are stable for at least two weeks. It is expected that in the near future, however, by the use of permanently sealed vials and perhaps inorganic salt solutions, more permanent standards may be devised.

SUMMARY

Rapid soil tests have occasionally been criticized because the results obtained by different workers using the same methods do not always agree. The desirability of standardized technique has been recognized by all engaged in this type of work and has led to the adoption in this laboratory

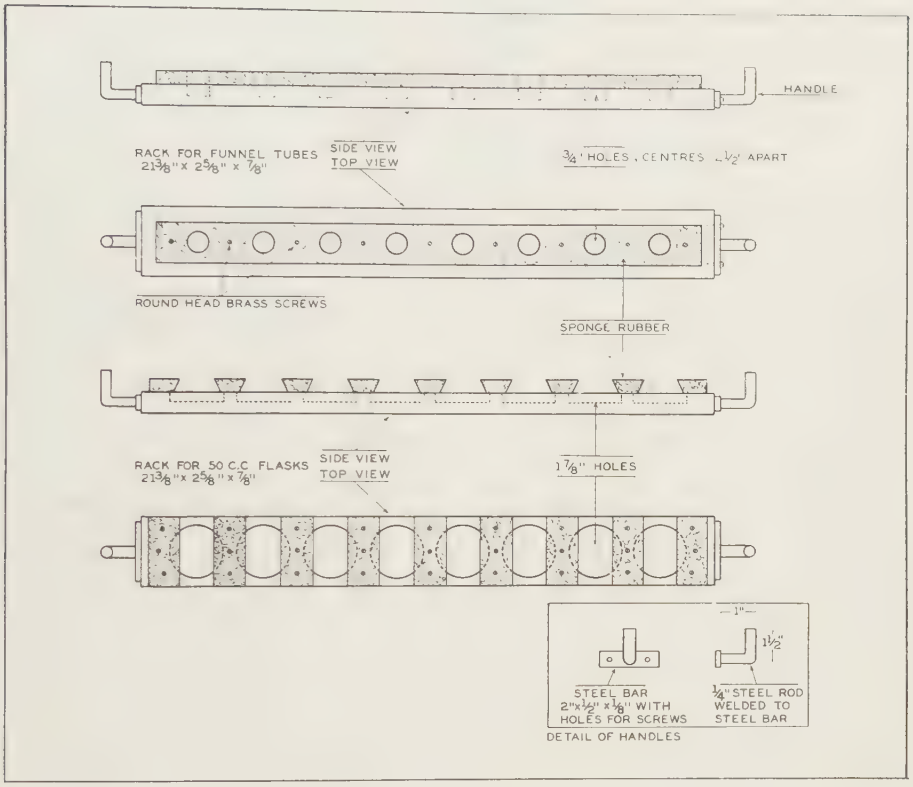


FIGURE 9. Detail of racks for holding glassware.

of various pieces of equipment designed to ensure reproducible results. At the same time many of the operations have been speeded up and much of the tediousness of routine analysis removed.

A shaking device, by means of which eight samples may be extracted simultaneously, has proved of considerable advantage over hand shaking in that it performs this task more rapidly and uniformly. Racks for holding the glassware have been found very convenient, and by the use of the jets described the tedious washing operation is greatly speeded up.

A rotator for mixing the alcohol with the soil-potassium extract, while perhaps no more rapid than hand mixing, lessens the liability of error inherent in this operation.

Permanent standards, used in conjunction with a suitable illuminator, simplify the reading of the tests and assist in eliminating errors in matching colours, caused by the personal factor.

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THE MATERNAL-LINE SELECTION METHOD OF BREEDING FOR INCREASED SEED-SETTING IN ALFALFA

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INTRODUCTION

This paper is presented for the purpose of describing the maternal-line selection method of breeding as developed and applied at the University of Alberta during the past 15 years for the improvement of seed-setting capacity in alfalfa. The success so far attained is also indicated.

In the year 1924 certain circumstances suggested that improvement in alfalfa varieties and biological studies on this crop were badly needed. These circumstances were as follows: *(a)* alfalfa was known to be notoriously irregular in seed production, particularly in semi-humid regions; *(b)* certain alfalfa plants had been noticed to set seed abundantly every year in locations known to be in poor seed producing areas, while other plants never set seed freely, this suggesting the likelihood that differential fertility among alfalfa plants has a genetical basis; *(c)* varieties of alfalfa had been observed to vary greatly in their ability to survive severe winter and spring conditions.

It was therefore decided late in 1924 to undertake a breeding programme with a view to developing, if possible, alfalfa stocks improved in certain particulars and especially in seed-setting capacity.

MATERIAL

For purposes of this project numerous diverse varieties and strains of alfalfa were procured so that the original breeding stocks might provide a wide variety of gene material upon which to work. The designations of these stocks are listed in Table I, Numbers 1 to 21 inclusive. The first stand of spaced plants was established in 1925. In the following year Numbers 22 and 23 of the table were added, and in 1930 five additional strains of Grimm alfalfa together with two selections from Southworth's hybrid, all originating from other projects and involving about 500 plants, were brought into the project.

THE METHOD

During the years 1924 to 1934 the method was evolved with the more important features being introduced early in this period. The history of this development need not be described here. It may be noted, however, that the following theoretical principles have been given due consideration in the design of the method: *(a)* continued selective breeding brings about an accumulation of genes contributing to the characters for which selection is made, with the simultaneous elimination of allelomorphic genes which

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TABLE 1.—VARIETIES OF ALFALFA AND NUMBERS OF PLANTS USED AS INITIAL MATERIAL IN THE BREEDING PROJECT

No.	Variety	Number of plants
1	Grafton (Brooks)	277
2	Wiley (Brooks)	287
3	Kirk (Sask.)	284
4	Grimm (1917 (Sask.)	95
5	Lyman (Brooks)	246
6	Daniels (Brooks)	209
7	Williams (Brooks)	236
8	Cossack (Sask.)	95
9	Early Michigan (Macdonald College)	96
10	Liscomb (Sask.)	93
11	Cherno (Sask.)	95
12	Baltic (Sask.)	81
13	Sand Lucerne U.S.D.A. No. 23394 (Sask.)	95
14	Turkestan U.S.D.A. No. 21032 (Sask.)	93
15	Argentine S.P.I. No. 56853	96
16	Hansen's Hybrid No. 1	92
17	Southworth's Hybrid (Man.)	36
18	Grimm Centurian (Macdonald College)	95
19	Obb (Sask.)	89
20	North Sweden (Macdonald College)	95
21	Medicago falcata S.P.I. No. 42714 (Russia)	74
22	Ontario Variegated (Guelph)	294
23	Disco (Brooks)	399

tend to develop detrimental or less desirable characters; *(b)* a wide diversity of initial material presumably provides a broad gene base for recombination and segregation; *(c)* a large population composed of numerous lines of cross-pollinating plants minimizes close breeding and its detrimental effects; *(d)* combined natural and artificial selection tends to build up an agrotype adapted to local ecological conditions and economic needs within the limits of the capability of the genes provided by the material; *(e)* the best plants in the best progenies provide the best propagating stock.

By 1934 the method in all its details, as now applied, was brought into use. Briefly, the method involves a sequence of four-year cycles. In the first year of the cycle a new stand of plants is established. This consists of about 80 progenies each containing approximately 50 plants. Each progeny occupies one row. The rows are 3.5 feet apart, and the plants in the rows are 3.5 feet apart. This arrangement allows all plants equal space and permits of easy examination of the individual plants. Seedlings may be started in the greenhouse and transplanted to the field, or the seed may be planted in hills (nests) directly into the field with four or five seeds to a hill and the seedlings later thinned to one in a place. The field chosen should be entirely free from seeds of alfalfa and of sweet clover, which have fallen from previously grown crops and which may volunteer in the new stand. The new stand is started in the field at Edmonton about June 15. In the second year the plants are allowed to set seed and about the middle of August the plants are examined and appraised individually for seed-setting capacity. A system of scoring is used to designate different degrees of seed-setting, each plant being scored 0, 1, 2, 3, 4 or 5 according to pod density as estimated by visual inspection.

(It was realized in the early stages of this project that some criterion was needed by which plants might be evaluated and classified relative to their potential genetic fertility or seed producing capacity. This criterion should be easy to apply so as to render practicable the handling of large plant populations. It should be independent of the size of the plant and therefore of the actual amount of seed produced by a plant in a given situation. It seemed that the most practical criterion would be the relative density, that is degree of crowdedness of pods on the plant irrespective of the size of the plant, and that the whole range of density for pods might be divided into about six categories commencing with the absence of pods, continuing through increasing degrees of density and ending with a very crowded condition of pods, particularly on individual racemes. It appeared desirable that the number of categories should be small so that typical plants for the different categories would differ quite decidedly and therefore be readily classifiable. These categories could be designated respectively 0, 1, 2, 3, 4 and 5 for reference purposes. It was thought that once the experimenter had formed in his mind rather definite concepts of the various categories, he would be able readily and quickly to evaluate individual plants and to score them with appropriate designations. This system of classifying and scoring was adopted and has been successfully used for several years.)

In the second year of the cycle any decidedly poor progenies or plants are removed and discarded.

In the third year all remaining plants are again scored for density of pods. This second scoring is thought advisable, since it appears that particular alfalfa plants are prone to react differently with respect to pod setting under the varying climatic conditions of different years. After scoring is completed in the third year about 100 of the best plants from 30 to 40 of the best progenies are selected on the bases of the combined scores for the two years and of favourable vegetative characteristics.

After evident improvement has been attained by the maternal-line selection method the seed may be harvested in the third year of each cycle from all approved progenies and bulked as foundation stock for increase purposes. Thus from each cycle a fresh supply of foundation stock may be secured, which by increasing may be made available to alfalfa growers generally.

In the fourth year of the cycle all plants except about 80 of the best previously selected plants are removed from the field. These 80 plants are allowed to set seed *in situ* under conditions of open pollination. This allows the selected plants to intercross among themselves only and not promiscuously with poorer non-selected plants. (The whole project is, of course, isolated as much as possible from other stands or plants of alfalfa). By this procedure the selection of maternal parents is under complete control, while that of the paternal parents is only partially so. The latter are, however, always high seed-setting plants. The seed thus obtained is used the following year to establish 80 new progenies for the beginning of a new four-year cycle.

RESULTS

Seed Setting

In 1934, while one of the cycle stands was being established, the mother plants which had been previously selected were allowed to set seed again after transplantation to a new location. Seed of 31 of these plants was harvested, bulked and given the designation I_M. 35-1. This bulked seed was then used in comparative tests for hay production and seed setting, with Grimm, Ladak, Cossack (three commonly grown local varieties) and a selfed line (S_2.32-31). The chief object of these tests was to determine whether or not any appreciable progress had been made by the application of the maternal-line selection method during previous years. The comparative hay and seed tests were set up separately on adjacent areas of land. The details of this experiment need not be described here except to say that varieties were randomized in four blocks in both tests, and that the plants in the hay test were arranged singly one foot apart in rows two feet apart and in the seed test they were arranged three feet apart each way. The pod-scoring method previously described was used for recording seed-setting for individual plants.

These tests were started in 1935 and records of results were made for 1936, 1937 and 1938. In the winter of 1936–37 a high mortality occurred among the plants in the seed plots. The surviving plants were used for scoring in subsequent seasons, and to data so obtained were added data of scores for plants in certain portions of the hay plots in which only plants with three-feet spacing both ways were used. Summarized data are given in Tables II, III, IV and V. The data for replicate plots have been combined. For example, in Table II the data for Grimm include the combined data for all plots of Grimm for 1936. The upper half of each table gives the actual frequencies of plants receiving the various scores, while the lower half gives these values in terms of percentage. Table V combines the results for all three years. In the various tables high percentages of plants of a variety scoring 0 or 1 indicate poor seed-setting ability, while high percentages of plants of a variety scoring 3, 4 and 5 indicate relatively high seed-setting capacity. The percentage values in the two right-hand columns in the tables may be taken as an indication of the relative fertility of the various varieties. In Table II it may be seen that for 1936 the percentages of plants scoring 3 and over, also 4 and over, are higher for Grimm than for Ladak and Cossack, and higher for Ladak than for Cossack. The selfed line (S_2.32-31) is slightly higher for percentages in these columns than Grimm. I_M.35-1, however, has corresponding percentages which are very much higher than those for any of the other varieties, which indicates that the fertility or seed-setting capacity of the improved strain is considerably greater than that for any of the other varieties. This same relationship holds for the 1938 data, but only partially for the 1937 data when all varieties and strains set seed much more abundantly than in either of the other two years. In 1937, also, however, the improved strain evidently set seed much more extensively than did any of the other varieties. For example, the improved strain and Grimm show 63.9% and 53.4% respectively for proportion of plants scoring 3 and over, and they show 40.5% and 16.6% respectively for the proportion of plants scoring 4 and over.

TABLE II.—ALFALFA PLANT DISTRIBUTION FOR POD-SETTING SCORES IN 1936

Variety or strain	Plant number								
	Total	Score							
		0	1	2	3	4	5	3 and over	4 and over
Grimm	215	2	124	70	16	3	0	19	3
Ladak	218	7	166	33	11	1	0	12	1
Cossack	229	19	193	16	1	0	0	1	0
Selfed line	216	5	120	68	17	5	1	23	6
IM.35-1	230	2	60	76	48	34	10	92	44
Total	1108	35	663	263	93	43	11	147	54
	Plant percentage								
Grimm		0.9	57.7	32.6	7.4	1.4	0	8.8	1.4
Ladak		3.2	76.1	15.1	5.1	0.5	0	5.6	0.5
Cossack		8.3	84.1	7.0	0.4	0	0	0.4	0
Selfed line		2.3	55.6	5.6	7.9	2.3	0.5	10.7	2.8
IM.35-1		0.9	26.1	33.0	20.9	14.8	4.3	40.0	19.1
General percentage		3.2	59.8	23.7	8.4	3.9	1.0	13.3	4.9

TABLE III.—ALFALFA PLANT DISTRIBUTION FOR POD-SETTING SCORES IN 1937

Variety or strain	Plant number								
	Total	Score							
		0	1	2	3	4	5	3 and over	4 and over
Grimm	144	2	31	34	53	13	11	77	24
Ladak	215	4	49	76	45	35	6	86	41
Cossack	218	11	58	60	57	26	6	89	32
Selfed line	209	10	72	52	33	26	16	75	42
IM.35-1	205	1	33	40	48	42	41	131	83
Total	991	28	243	262	236	142	80	458	222
	Plant percentage								
Grimm		1.4	21.5	23.6	36.8	9.0	7.6	53.4	16.6
Ladak		1.9	22.8	35.4	20.9	16.3	2.8	40.0	19.1
Cossack		5.0	26.6	27.5	26.1	11.9	2.8	40.8	14.7
Selfed line		4.8	34.5	24.9	15.8	12.4	7.7	35.9	20.1
IM.35-1		0.5	16.1	19.5	23.4	20.5	20.0	63.9	40.5
General percentage		2.8	24.5	26.5	23.8	14.3	8.1	46.2	22.4

TABLE IV.—ALFALFA PLANT DISTRIBUTION FOR POD-SETTING SCORES IN 1938

Variety or strain	Plant number								
	Total	Score							
		0	1	2	3	4	5	3 and over	4 and over
Grimm	146	1	97	36	10	2	0	12	2
Ladak	216	1	168	35	12	0	0	12	0
Cossack	207	8	174	24	1	0	0	1	0
Selfed line	210	6	127	53	17	6	1	24	7
IM.35-1	208	0	92	45	49	20	2	71	22
Total	987	16	658	193	89	28	3	120	31
	Plant percentage								
Grimm		0.7	66.4	24.7	6.8	1.4	0	8.2	1.4
Ladak		0.5	77.7	16.2	5.6	0	0	5.6	0
Cossack		3.9	84.0	11.6	0.5	0	0	0.5	0
Selfed line		2.9	60.5	25.2	8.1	2.8	0.5	11.4	3.3
IM.35-1		0	44.2	21.6	23.6	9.6	1.0	34.2	10.6
General percentage		1.6	66.7	19.6	9.0	2.8	0.3	12.1	3.1

TABLE V.—ALFALFA PLANT DISTRIBUTION FOR POD-SETTING SCORES FOR THREE YEARS COMBINED (1936 TO 1938).

Variety or strain	Plant number								
	Total	Score							
		0	1	2	3	4	5	3 and over	4 and over
Grimm	505	5	252	140	79	18	11	108	29
Ladak	649	12	383	144	68	36	6	110	42
Cossack	654	38	425	100	59	26	6	91	32
Selfed line	635	21	319	173	67	37	18	122	55
IM.35-1	643	3	185	161	145	96	53	294	149
	Plant percentage								
Grimm		1.0	49.9	27.7	15.6	3.6	2.2	21.4	5.8
Ladak		1.8	59.1	22.2	10.5	5.5	0.9	16.9	6.4
Cossack		5.8	65.0	15.3	9.0	4.0	0.9	13.9	4.9
Selfed line		3.3	50.2	27.3	10.6	5.8	2.8	19.2	8.6
IM.35-1		0.5	28.8	25.0	22.6	14.9	8.2	45.7	23.1

In Table V, in which the data for the three years are brought together, the same general relationship between varieties and strains holds as for the three years individually. For I_M.35-1 and Grimm, the data for plants scoring 3 and over are respectively 45.7% and 21.4%, and the data for plants scoring 4 and over are 23.1% and 5.8% respectively.

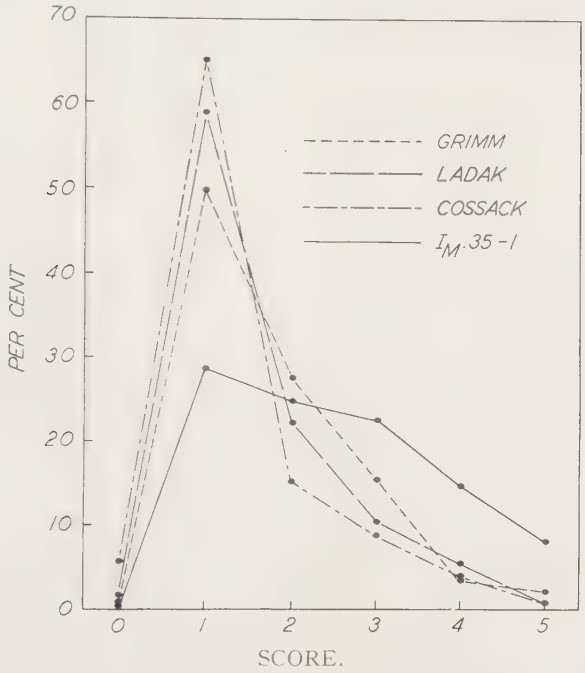

FIGURE 1.—Percentage of alfalfa plants of Grimm, Ladak, Cossack and I_M.35–1, scoring 0 to 5 during three years at Edmonton.

Figure 1 shows in graphic form the three-year relationships among the varieties and strains with respect to scores for pod setting. The line for S_2.32-31 is very similar to that for Grimm and has been omitted from the graph in order to avoid confusion. The graph shows clearly the contrast between Grimm, Ladak and Cossack on the one hand and I_M.35-1 on the other for proportions of plants scoring 1 and the reverse relationship for proportions of plants scoring 3, 4 and 5.

The tables and the graph indicate a very decided distinction between I_M.35-1 and the other varieties for fertility or seed-setting capacity. It seems not unreasonable to conclude that the improved strain is probably at least 100% superior to Grimm and still more superior to Ladak and Cossack in fertility *under Edmonton conditions.*

Hay Yields

It might be asked whether or not the increased seed-setting capacity of the improved stock, I_M.35-1, was effected at the expense of fodder yielding capacity. This question may be answered by a presentation of

data derived from the hay test of these varieties and strains, which was conducted concurrently with the seed-setting test. Table VI gives average yields in tons per acre of cured hay for the three varieties and two strains for three years.

TABLE VI.—AVERAGE ANNUAL YIELD IN TONS OF CURED HAY PER ACRE FOR THREE VARIETIES AND TWO STRAINS OF ALFALFA FOR 1936 TO 1938 INCLUSIVE

—	Grimm	Ladak	Cossack	S_2.32-31	I_M.35-1
First cutting	2.110	2.255	2.154	2.168	2.213
Second cutting	1.509	1.418	1.455	1.444	1.455
Two cuttings	3.619	3.673	3.609	3.612	3.668

The average annual yields from the two cuttings of hay for these varieties and strains are so nearly equal that the differences are not significant, and it may be concluded from this that the improved strain, I_M.35-1, has not lost any of its hay yielding capacity while its seed-setting capacity was being improved.

The improved alfalfa appears definitely to be superior in seed-setting capacity at Edmonton, and the next undertaking was a determination of its behaviour in various locations in the province, where conditions are considerably different from those ordinarily prevailing at Edmonton. This undertaking was started in 1937 at eight scattered points in Alberta, and the first results were obtained in 1938. The new strain outyielded for seed Grimm and an Ottawa strain, with which it is being compared, in all cases with the exception of Grimm at one point. This comparative test is to be continued at these various points for at least two more years after which it is the intention to publish complete results.

SUMMARY

1. A description is given of the maternal-line selection method of breeding as developed at the University of Alberta for the improvement of seed-setting in alfalfa. This method involves four-year cycles, following each other indefinitely. In the first year a relatively large population is established from seed, involving 60 to 80 progenies arranged side by side, all plants being spaced three and a half feet apart each way, so as to allow all plants equal and ample growing space. In the second year all plants are scored individually for fertility as indicated by the density of pods on the plant, score symbols 0, 1, 2, 3, 4 and 5 being used for increasing degrees of pod density. Decidedly poor progenies and plants are destroyed. In the third year all surviving plants are again scored for fertility. In the late summer the best plants in the best progenies are selected to the extent of about 100 plants from 30 or 40 progenies, based on the combined scores for both years and also on the vegetative characteristics of the plants. (After a few cycles when evident improvement has been attained seed may

be harvested in the third year of each cycle from all approved progenies and bulked for increase, thus providing every four years indefinitely new foundation stocks for increase and distribution to commercial alfalfa seed growers). In the fourth year all plants except about 80 of the best selected plants are removed from the field. These 80 plants are allowed to set seed *in situ*, under conditions of open pollination. The whole project is, of course, isolated as much as possible from other stands or plants of alfalfa. The seed thus obtained is used the following year to establish 80 new progenies for the beginning of a new four-year cycle.

2. In a three-year test at Edmonton, alfalfa stock which had been under the maternal-line selection method of improvement for ten years showed very decided superiority in fertility over ordinary unimproved Grimm, Ladak and Cossack varieties and a selfed line.

3. In a concurrently conducted three-year hay test it was shown that selection for high seed-setting capacity had not resulted in any reduction of hay yielding ability.

4. Results for the first year of a seed yield test of the improved stock in comparison with Grimm and an Ottawa strain conducted at eight widely scattered points in Alberta suggest that this stock may yield seed more abundantly than these stocks at other points in the province as well as at Edmonton.

ACKNOWLEDGMENT

The author is indebted to Dr. K. W. Neatby, University of Alberta, for reading and criticising the manuscript for this paper, and to Mr. J. J. Sexsmith for drawing the graph used in Figure 1.

SOIL MOISTURE STUDIES

I. SOME FACTORS AFFECTING THE MOISTURE HOLDING CAPACITY AND ITS DETERMINATION[1]

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In 1931, a series of investigations was initiated at Kelowna into the cause and control of drought spot and corky core of the apple. In view of the previous findings of McLarty (16) that these disorders were associated in some way with soil moisture, a large part of the investigational work was centred around irrigation and soil moisture problems. With the discovery by McLarty (17) in 1935 that the primary cause of the disorders was a deficiency of boron, the subsequent work on soil moisture has been applied more specifically to practical irrigation and soils classification problems. The effects of irrigation on drought spot and corky core have already been reported by the writer (32). In the series of papers of which this is the first, it is proposed to present the major findings of the soil moisture work from 1931 to 1938. This present paper embodies a report of the studies that have been made on factors affecting the moisture holding capacity of the soil. The term "moisture holding capacity" is used here in its usual connotation of the capacity of a wetted soil to hold moisture after the gravitational water has been allowed to drain off (3, 24, 13, 22). It is expressed as a percentage of the dry weight of the soil.

REVIEW OF LITERATURE

The moisture holding capacity of the soil has been studied by a large number of investigators, who have published an enormous amount of valuable data. It would be outside the scope of this paper to attempt to review all of this work. However, brief mention will be made of some of the major findings dealing with the factors affecting the moisture holding capacity.

(a) Type and Depth of Soil

It has been common experience (14, 1, 9, 12, 25) that the "heavier" a soil, or the greater the colloid content, the more water is retained against gravity. In spite of this, Loughridge (14) did not obtain a high correlation between the mechanical analysis and the moisture holding capacity. Lebedeff (12) used soil separates, and found that the smaller the particles, the more water was retained. Olmstead (21) obtained a high correlation between the moisture holding capacity and the percentage clay. Haines (5) found with both glass beads and soil that the smaller the diameter o the pores, the more water was held at any one pressure deficiency. Stephenson and Schuster (25) estimated that a soil pore 10 microns in diameter is the largest that will normally hold water against gravity. They also pointed out that in a heavy soil there may be so little drainage after

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saturation with water that the moisture holding capacity and the saturation capacity practically coincide. Mattson (15) noted that in a heavy soil the moisture holding capacity may be affected by the silica-sesquioxide ratio and by the nature of the cations present in the base exchange. In any one soil type, laboratory tests of the effects of different degrees of packing have indicated that the looser the soil, the higher the percentage of moisture retained (6, 19, 10). In any one soil type, also, the depth of the soil column has been found to affect the percentage of moisture held. When measured above a water table, the moisture holding capacity lessens with greater distance above the free water; hence the longer the column of soil above the water, the less the average percentage of moisture retained (14, 4, 20, 29, 8). Wadsworth (29) found that if the moisture was allowed to rise from a water table into dry soil until offset by gravity, the moisture content at or near the top of the wetted soil would represent the true moisture holding capacity.

(b) Type of Drainage

The type of drainage has been found to exert a considerable influence on the amount of water retained in the soil. Widtsoe and McLaughlin (30) reported that drainage over a wire screen was not as rapid as drainage under field conditions with no water table present. Later, McLaughlin (18, 19) found that drainage over a screen was much less than that over a water table. A number of investigators (1, 18, 24, 26, 27, 23, 21, 22) have used drainage into a comparatively dry soil as a standard of comparison, and have pointed out that the results obtained in other ways did not always conform to this standard. Israelsen (7), Veihmeyer (26), and Veihmeyer and Hendrickson (27, 28) found that the application of water to a comparatively dry soil in the field was accompanied by an initial rapid spread of the moisture, followed by a very slow further spread. When the rapid spread was completed, the soil was considered to be wetted to the moisture holding capacity. The heavier the soil, the longer time was required for this point to be reached. With the soils studied, the best time of sampling was found to be two to three days after irrigating (28). Other investigators have made different approximations of the time at which the major part of the drainage has taken place. Widtsoe and McLaughlin (30) sampled at 24 hours, Israelsen (8) at 1 to 2 days, and Lewis, Work and Aldrich (13) at 1 to 2 days in sandy soils and much longer in heavy soils. Olmstead and Smith (22) pointed out that drainage may occur for varying lengths of time depending on the soil type. In laboratory studies, Lebedeff (11), Shaw (24), Olmstead (21) and many others have used dry soil as the medium of drainage. Shaw (24) wetted only part of the soil column, so that drainage was into dry soil of the same kind as that wetted. Lebedeff (11) found that when a fine soil was drained into a dry coarse soil, it retained more water than when drained into a dry fine soil. This was attributed to the greater capillary pull of the dry fine soil for water. Similar results were obtained in field work by Veihmeyer and Hendrickson (27).

PURPOSE OF INVESTIGATION

Early in the course of the field studies made on soil moisture, it became obvious that these studies would need to be supplemented by laboratory

studies. For one thing, it seemed desirable to establish a laboratory technique for determining the moisture holding capacity. Although field determinations should be the more reliable, various difficulties were encountered in making them—such for instance as in non-irrigated districts or in virgin soils. In many cases, also, the time involved in making field determinations became a serious consideration. It also seemed desirable to use a laboratory method that would approximate as closely as possible to field conditions. There were various reasons for this. In the first place, it was hoped that comparisons could be made between field and laboratory determinations on different sets of soil samples. In the second place, it was anticipated that a direct application could be made to irrigation practices; for example, the planning of an irrigation system, or practical recommendations for the application of water. Later in the investigation, the possibility also presented itself of using the moisture holding capacity as a basis for soil classification.

Preliminary investigations in both the field and the laboratory indicated that accomplishing the above purpose would not be an easy undertaking. For one thing, there appeared to be a great deal of variability in moisture holding capacity in the field, even within the one soil type. In the laboratory, determinations made by some of the methods in common use gave widely varying results. Accordingly, before any one specific method was to be selected for use, it was considered worth while investigating the major factors affecting the retention of water, both in the field and in the laboratory.

FACTORS AFFECTING THE MOISTURE HOLDING CAPACITY IN THE FIELD

In view of the extended nature of the investigational work of the past 8 years, no attempt will be made to report the results in detail. Instead, a brief resume will be presented of the findings with respect to the effects of each factor studied.

(a) Soil Type

As would be expected, high correlations were found between soil type and the moisture holding capacity. The most comprehensive studies of this factor involved the determination of the moisture holding capacity of 100 samples in the field, collected at a depth of 12 inches and at 24 hours after irrigating. These samples varied from a coarse sand to a heavy clay. Mechanical analyses were made by R. H. Spilsbury of the Department of Agriculture Soils Survey staff, using the Bouyoucos hydrometer method (2). The following correlations were obtained, using only those samples not affected by seepage water or other such abnormal conditions:

Moisture holding capacity and percentage sand	−0.930
" " " " percentage silt + clay	+0.930
" " " " percentage colloid	+0.886

These correlations were exceptionally high, and indicated a very close relationship between soil type and the moisture holding capacity. It will be noted that the correlations with sand and with silt-plus-clay were of

the same size but were opposite in sign. It is obvious that the actual correlation was with the silt-plus-clay, that with sand resulting from the fact that its value was always complimentary to that of the silt-plus-clay. An examination of the scatter diagrams used in these studies revealed much lower correlations when the percentage silt and the percentage clay were correlated separately with the moisture holding capacity than when they were combined as above. Further data obtained on these 100 samples of soil will be presented in the second paper of this series.

(b) Time after Irrigation

It was found that the heavier the soil, the longer was the time required for the excess soil moisture to drain off as gravitational water. Hence the use of any one constant time of sampling after an irrigation would constitute a source of error. This problem was found to be still more complicated under orchard conditions by the rapid withdrawal of water by the plant roots. In fact it was impossible to determine the exact point at which the decrease in moisture attributable to drainage ceased, and that attributable to utilization by plant roots commenced. As a working compromise, a standard time of 24 hours after irrigating was used in all the other field tests reported herein.

(c) Depth of Sampling

In any one soil type, and at any one time after irrigating, the degree of drainage was found to be different at different depths. When the subsoil was quite moist, the lower horizons drained more slowly than the upper horizons; but when the subsoil was comparatively dry, the lower part of the wetted soil usually lost its excess moisture more rapidly than the upper part. At any one depth, moreover, the rate of drainage was found to be slower in a heavy soil than in a light soil. Hence the use of any one time after irrigating would introduce another source of error. Yet correction for this error was found to be almost impossible under field conditions. In studying the effects of other factors, soil samples were taken at a standard depth of one foot.

(d) Type of Subsoil Drainage

In a few of the cases studied, percolation into the subsoil was prevented by hardpan or heavy clay layers. More frequently, however, the subsoil was comparatively dry, and thus exerted a capillary pull on the water in the wetted soil adjacent to the furrows. In such cases, the wetting of the soil between the furrows was accomplished almost entirely by capillary action. Any wide variation in the type of subsoil was found to affect markedly the removal of water by capillary action: as long as the subsoil was not heavy enough to be of a hardpan nature, the heavier it was the greater was its pull on the moisture above. The reverse held true when the subsoil was wet. As a general rule, the moisture held by any one soil type over either gravel or heavy clay was found to be greater than that held over silt, loam or fine sand. In all studies involving the irrigation of a comparatively dry soil, a definite line of demarcation was found between the wet and dry areas in the soil, the same as reported by Veihmeyer (26, 27, 28). After irrigation was stopped, the more rapid spread of the water was followed by a very slow spread, which produced a gradual feathering out of the line of demarcation.

FACTORS AFFECTING THE MOISTURE HOLDING CAPACITY IN THE LABORATORY[1]

All the laboratory determinations of the moisture holding capacity reported herein were made with the use of galvanized iron tubes 2 inches in diameter and 3 inches in height. As in the case of the field studies, brief mention will be made of the more important factors found to affect moisture retention.

(a) Grinding and Packing of Soil

Grinding was accomplished with a wooden or rubber pestle, and packing with a metal tamper. Soil in the air-dry condition was used in all cases. It was found that with uniform packing, the finer the grinding of the soil, the more was it compacted, and the less moisture was retained against drainage. With uniform grinding, an increase in the degree of packing was accompanied by an increase in volume weight and a decrease in the moisture holding capacity. These effects were quite marked with heavy soils, but almost negligible with sandy soils.

(b) Method of Wetting the Soil

Before drainage, the tubes of soil were in all cases saturated with water. Wetting from the top down resulted in many cases in the trapping of air in pockets, but wetting from the bottom up by complete immersion gave quite satisfactory results. All external swelling, above the top of the tube, was effectively prevented by placing a flat 5-pound weight on top of the soil column.

(c) Type of Drainage

Gravitational water was removed by various types of media below the soil column, such as a wire screen, wet soil, air dry soil, oven dry soil, and soil at the wilting point. Drainage over a wire screen and over wet soil was extremely slow in almost all soil types, in comparison with that over dry soil. No measurable effect was obtained by varying dryness of the soil below, between the oven-dry state and the wilting point. Tests were also made with soils of different type as drainage media, all in the air dry condition. The effects were quite marked: the heavier the soil below, the more rapid the loss of water by the soil above. Here is an example of the effects on a sandy soil, expressed in terms of percentage dry weight:

Saturation with water	19.5% moisture
Over a wire screen for 6 hours	19.0% moisture
Over same soil for 6 hours	16.0% moisture
Over a heavy clay for 6 hours	6.6% moisture.

(d) Length of Soil Column

Columns varying in length from 3 inches to 4 feet were set up, by the simple process of packing the soil in the 2 × 3-inch tubes and placing them end to end to the required length. Drainage was into air dry soil of the same kind in all cases. In general, the longer the columns the more water was retained, though this effect was not very marked. During the initial

[1] This section is a partial summary of a thesis submitted in 1933 by the author to the Department of Horticulture at the University of British Columbia, in partial fulfilment of the requirements for the degree of Master of Science in Agriculture (31).

rapid loss of moisture, the lower sections of the longer columns contained somewhat more moisture than did the upper sections. After that, however, there was very little difference between the lower and upper parts. The initial rapid loss of moisture was much slower in the heavier soils but continued longer in them than in the lighter soils. With any one soil, the longer the column the more time was required for drainage to comparative equilibrium (*i.e.*, with further losses very slow). Drainage of 3-inch columns for half an hour gave practically the same results as drainage of 4-foot columns to the point of equilibrium.

(e) Soil Type

A high correlation was obtained between soil type and moisture retention. The methods used, and the results obtained, are outlined briefly in the section below. Tests were also made of the effects of mixing samples of different soil types. It was found that when adjustment was made for the percentage of each soil in the mixture, the results constituted a fairly reliable average of the individual samples used. The purpose of these tests was to gain some idea of the effects of using a composite soil sample from several horizons in the field to represent the profile as a whole. The results indicated that such a procedure should be quite satisfactory.

A LABORATORY APPROXIMATION OF FIELD RESULTS

As noted above, one of the objects of the soil moisture investigations was to establish a method of determining the moisture holding capacity in the laboratory that would approximate field conditions. It can be seen from the findings just presented that this object would not be easy to accomplish. The primary difficulty was the variability in the moisture held in any one soil type, under varying conditions of soil depth, type of drainage, rate of drainage, and rate of moisture utilization by the roots. Obviously, it was quite impossible to develop a laboratory method that would give satisfactory results under all conditions. However, it was felt that if those conditions that are more commonly found in orchards in the Okanagan Valley were used as a basis, the method developed on this basis might then be applied, with some adjustments in interpretation, to other orchard conditions. After a large number of soil profiles had been studied, it was decided to assume the following: (1) a deep, uniform soil with good drainage, (2) a comparatively dry soil preceding irrigation, (3) a balance between drainage and root utilization of moisture at 24 hours after irrigation.

In developing a laboratory method that would approximate the above conditions, it was necessary, first, to determine the degree of packing required to give the same volume weight as in the field. With the assistance of T. H. Joy, mechanic at the Laboratory of Plant Pathology, Summerland, a small tamping machine (Figure 1) was built for standardizing the degree of packing. It consists primarily of a steel propellor that can be weighted as desired and dropped onto the soil surface. By turning a handle, the propellor can be raised, released, and turned one-sixth of a turn at the one operation. The soil height is regulated with wooden slides, so that the distance the propellor drops is kept within narrow limits. This machine was made more specifically for use with tubes 2 inches in diameter

and 3 inches in height. Soil samples of known volume were then obtained in the field in different soil types, and at depths down to 5 feet. This was done by various methods, the most satisfactory of which was the use of a specially-made sampling can 3 inches in diameter and 4 inches deep. The soil samples were all sieved and air dried, and an attempt was made to tamp them in such manner and degree that the volume weight obtained would be the same as that in the field. In general, the deeper the sampling the more tamping was required to accomplish this. However, light soils required much less tamping than heavy soils, irrespective of depth, while samples from the B horizon (area of salt and colloid deposition) frequently could not be packed enough by the above method to give the correct results. At positions less than 8 inches in depth, the soils were much looser and varied a great deal more in volume weight than below this depth. On the whole, the most consistent results were obtained on samples from depths of 1 to 2 feet. Accordingly, it was decided to tamp the soil to approximate the volume weight at this depth, and to assume thereafter that all samples taken in the field came from the same depth. After a long series of comparisons with samples taken in orchard soils, a procedure was finally adopted involving a standard method of drying the soil, sieving it, sifting it into the 2 × 3 inch tubes, weight on propellor, and number of tamps to be given, that appears to work very satisfactorily.

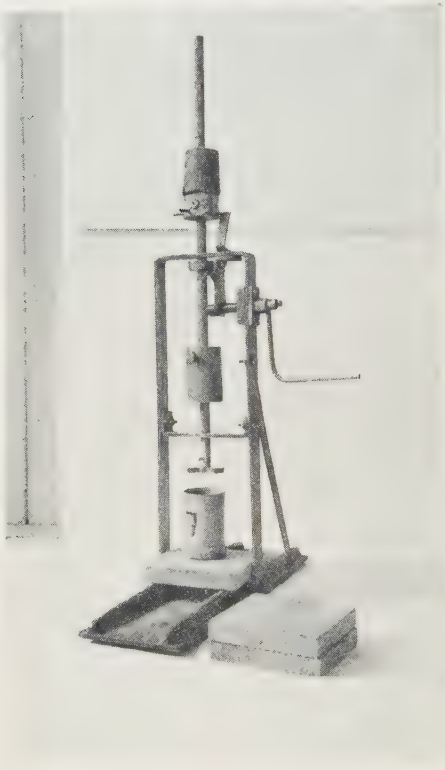

FIGURE 1. Soil tamping apparatus, for use in packing the soil into 2 by 3 inch tubes. It consists of a weighted propellor that falls onto the soil surface, the framework for holding it, and a handle that raises, releases and turns it in one operation. The soil height is regulated with wooden blocks.

The next step in the investigation was to test the amount and type of drainage required to give the same moisture content as that found at 1 to 2 feet in the field, and at 24 hours after an irrigation. Owing largely to the difficulty of complete standardization in field sampling, absolute uniformity in results was not obtained. The procedure finally adopted was as follows:

(1) Pack two 2 × 3 inch tubes (with screen bottoms) with the same soil, in the air-dry condition.

(2) Saturate one tube with water. Weigh.

(3) Fit a piece of blotting paper over the dry tube, invert the wet tube over it, weight it to maintain contact, and allow to drain for one-half hour. Weigh again.

(4) Dry at 105° C. for 24 hours. Weigh.

From the data thus obtained can be calculated the volume weight, specific gravity, percentage air space, air-dry moisture content, saturation moisture content, and moisture holding capacity.

For 3 years (1935 to 1937), comparisons were made between the field and the laboratory determinations of moisture holding capacity. In most cases, the laboratory method gave very little if any error, though there was some tendency for the silty soils to retain a little more moisture than under field conditions. Where there was any distinct discrepancy, it could be attributed largely to field variability. In 1937, the following correlations were obtained on 62 samples:

Laboratory method and field method	+0.674
Field method and % sand	−0.669
Laboratory method and % sand	−0.897

The mechanical analyses on these samples were made by R. H. Spilsbury, of the Department of Agriculture Soils Survey staff. It will be noted that the correlation with percentage sand was much closer by the laboratory method than by the field method.

Further reference will be made to the determination of the moisture holding capacity in the second paper of this series.

SUMMARY

A field and laboratory study was made of several factors affecting the moisture holding capacity of the soil.

The moisture holding capacity in the field was found to be affected by the following factors: *(a)* Type of soil. There was a high positive correlation with percentage silt-plus-clay. *(b)* Time after irrigation. The heavier soils drained more slowly. Utilization of moisture by the plant roots affected the rate of drainage. *(c)* Depth of sampling. Some variability was found in moisture retention as affected by depth. *(d)* Type of subsoil drainage. A dry soil below induced greater drainage than did a wet soil. The heavier the soil below, the greater was its capillary pull when dry. Drainage was less, however, above either heavy clay or gravel than above other soil types. A great deal of variability was found in the moisture holding capacity of any one soil type.

The factors studied in the laboratory included grinding and packing of the soil, method of wetting, type of drainage, length of soil column, and soil type. The findings were similar to those made in the field.

A laboratory method was developed that approximated field results very closely. The soil was tamped in 2 × 3 inch tubes with a standard degree of packing, saturated with water, and drained for one-half hour over air-dry soil of the same kind packed in a similar manner.

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PRESENT STATUS OF THE APPLE ROOTSTOCK AND DOUBLE-WORKING TRIALS IN EASTERN CANADA[1]

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INTRODUCTION

Investigational work in selecting and testing rootstocks and stem builders resistant to low temperature has been in progress at the Horticultural Division, Central Experimental Farm, Ottawa, since 1895. More recently, due to the stimulus created by the outstanding results attained at the East Malling Research Station in England, intensive investigations have been initiated with vegetative rootstocks at the Provincial Horticultural Experiment Station, Vineland, Ontario; the Horticultural Division, Ottawa; and the Dominion Experimental Station, Kentville, N.S.

HARDY ROOTSTOCKS

In the Eastern Ontario, Quebec and New Brunswick fruit districts, hardiness or resistance to withstand cold is essential in a rootstock. The Horticultural Division at Ottawa has been conducting trials since 1895 with the object of finding a uniformly hardy rootstock, and much valuable information has been accumulated. The records show that seedlings of varieties of crabs like Quaker Beauty, Martha, Transcendent and Hyslop together with those of the hardiest of the Russian varieties such as Anis, Antonovka, and Charlamoff may be used year after year as understocks for all the commercial varieties with little danger of losing a tree from root-killing. Trees propagated on these hardy rootstocks, providing they are not scion rooted, may be grown without loss of trees from root injury, whereas, occasionally, due to unfavourable environmental conditions, such as lack of snow coverage during the severe winter months, the trees on French Crab rootstocks kill out badly. This killing may be due to the apparent tenderness of the French Crab seedlings or lack of hardiness of the scion roots which are particularly numerous on root grafted trees.

Collar rot, which has been shown to be caused by a specific fungus, is responsible for quite a toll of trees each year in our eastern orchards. In the Horticultural Division varietal orchard, where all varieties are worked on hardy rootstocks, collar rot is seldom a problem. On the basis of this information coupled with similar findings in the various fruit districts in the United States, it would appear that a great deal of the collar rot injury so noticeable in our commercial plantings can be eliminated by employing hardy rootstocks highly resistant to this trouble.

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[1] Contribution No. 541 from the Division of Horticulture, Central Experimental Farm, Ottawa, Ontario. An address delivered before the Horticultural Group of the C.S.T.A. at the Nineteenth Annual Meeting of the Canadian Society of Technical Agriculturists at Vancouver, B.C., June 19 to 22, 1939.

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As a result of these investigations the Horticultural Division is now recommending Anis and Antonovka seedlings, which are vigorous growers, as standard rootstocks to replace the French Crab seedlings in eastern Ontario, Quebec and New Brunswick.

Extensive trials are now being conducted to compare the performance, as to hardiness, vigour, precocity, productivity, and longevity of the eastern commercial varieties when propagated on seedling roots of a large number of hardy varieties, *viz:*— Beautiful Arcade, *Malus baccata*, *Malus malus*, *Malus robusta*, *Malus sylvestris*, Patten Greening, Green Sweet, Moscow Pear, Charlamoff, Tetofsky, Columbia, Osman, Trail, Piotosh, Beauty, Hopa Crab and Dolga. These trees have not been established for a sufficient length of time to make any definite recommendations, but at present those growing on Beautiful Arcade, Patten Greening, and *Malus baccata* are particularly outstanding as to vigor, and the seedling roots themselves appear fully hardy.

VEGETATIVE ROOTSTOCKS

Generally speaking, apple trees in the Canadian orchards propagated on seedling rootstocks are vigorous growers and do not come into bearing at an early age. In the English orchards, trees growing on vegetative rootstocks are less vigorous, thus more economical to prune, spray, and pick; they also come into bearing at an earlier age. To establish if these practical advantages are applicable under Eastern Canada conditions, extensive experiments were initiated.

The first large scale experimental plantings of commercial varieties on East Malling vegetative stocks were made at Vineland Experimental Station in the fall of 1929 and at Kentville Experimental Station in the spring of 1930. The varieties and rootstocks planted at Vineland were as follows: 16 trees of each variety on each stock, R.I. Greening, Melba, Delicious, Spy and McIntosh propagated by budding on French Crab, E.M. No's I, II, XVI and a few trees of each variety on E.M. No. IX. The combinations set out at Kentville were: Crimson Gravenstein, Cox Orange, Red Stark and Red Spy on E.M. No's I, II, VI, IX, XII, XIII and XVI. An additional planting was made at Kentville in 1934— McIntosh and Fameuse budded on Anis and Beautiful Arcade, E.M. No's I, II, IX and XII. A comprehensive vegetative rootstock investigation was planted at the Horticultural Division, Ottawa, in 1936 consisting of the following combinations: McIntosh and Fameuse propagated on Anis, Antonovka, E.M. No's I, II, IX and XII.

Upshall (5, 6, 7) reporting on the East Malling rootstock trial at the Vineland Station presents data to show that the trees on E.M. No. IX come into bearing earlier than the trees on French Crab and, considering their smaller bearing area, produce much heavier crops in the earlier years in the orchard; moreover, that the fruit ripens earlier and is of higher colour than fruit produced on French Crab stock. The results show that the varieties perform differently with respect to size, precocity and productiveness on this stock, the greatest effect being the hastening of early fruiting in the late bearing varieties, Spy and Delicious. In the seventh year after

planting, the McIntosh trees on French Crab took the lead over those on E.M. No. IX and in the eighth year the Melba on French Crab passed those on E.M. No. IX; the other three varieties on E.M. No. IX are still in the lead. It is quite evident from the data presented, that if the trees on E.M. No. IX were planted 12 feet × 12 feet the early yields on the acre basis would be considerable. Under Vineland conditions trees propagated on this stock seem to be admirably suited for general backyard use. It is further observed that trees growing on E.M. No. IX must be staked to prevent blowing over and breakage below the graft union. Moreover, they must be planted shallow so that the union is at least two inches above the ground level to prevent scion rooting. The results attained at Kentville Station (8) indicate strongly that E.M. No. IX is not a desirable understock in the Annapolis and Cornwallis Valleys due to poor root development in the soils prevailing there. At Ottawa (9) the McIntosh trees propagated on E.M. No. IX came into fruiting the third year after planting, while those on seedling stocks of Anis and Antonovka are still quite vegetative. It would appear from the findings to date that E.M. No. IX will become a very desirable understock for trees intended for planting in home gardens in Eastern Ontario and Quebec. It is, however, of doubtful value in commercial orchards in these fruit districts, since it is improbable that the growers would give the necessary attention to staking.

At the Vineland Station (5, 6) trees growing on E.M. No's I and II are smaller and more precocious than those on French Crab and E.M. No. XVI. The E.M. No. II trees are larger than the E.M. No. I trees and are more productive to date. Trees on E.M. No. I appear to be more susceptible to potash deficiency than other stocks. Under Vineland conditions E.M. No. II is preferable, so far, to E.M. No. I, and would seem to offer some promise of meeting the demand for a smaller tree. In three varieties the trees on French Crab are larger than those on E.M. No. XVI with the reverse true with the other two, and except with R.I. Greening the Malling trees have been poorer croppers than those on French Crab. Since the data presented in (5, 6) indicate that there is no reduction of variability in tree size by the use of clonal stocks over that of seedling stocks, there seems to be no good reason for using E.M. No. XVI rootstock in the Niagara Fruit Belt. The findings to date at Kentville (8) in respect to E.M. No's I and II are just the opposite to those obtained at Vineland, the E.M. No. 1 trees being larger and yielding more fruit per tree than those on E.M. No. II. E.M. No. I seems well adapted to conditions in the Annapolis and Cornwallis Valleys and a large number of trees propagated on this stock have already been planted in the commercial orchards. E.M. No. II also seems satisfactory to use under their conditions in the development of semi-vigorous trees. Trees on E.M. No's VI, XII, XIII and XVI appear to perform much like those trees on French Crab seedlings at Kentville, and there seems no good reason why they should be employed commercially. In the Ottawa (9) trials there is no significant difference to date in the performance of the McIntosh trees on E.M. No. I and E.M. No. II and the trees on these stocks are intermediate in their growth rate between those on Anis, Antonovka, E.M. No. XII and those on E.M. No. IX rootstocks, further, are more precocious, bringing McIntosh into fruiting four years after planting. The growth rate of McIntosh trees

growing on Anis, Antonovka and E.M. No. XII rootstocks is similar and of a vigorous nature. Vegetative stocks of the same vigor as Anis and Antonovka would appear to be of no value in Eastern Ontario and Quebec orchards since their performance to date is equally as variable as those on seedling roots. Moreover, these stocks are definitely not as hardy as the Russian seedling roots. E.M. No. I and II appear promising at Ottawa as semi-vigorous stocks but their hardiness must be thoroughly established before they can be recommended for commercial use in Eastern Ontario, Quebec and New Brunswick.

More recently, further trials have been laid down by the Dominion Department of Agriculture at the Horticultural Division, Ottawa; Experimental Station, Cap Rouge, and on a privately owned farm at Maitland, Ontario. Many vegetative rootstocks are included in these trials, E.M. No's I, II, IX, X, XII, XIII, XIV and Crab C, together with five hardy clones developed by the Horticultural Division, namely, Ottawa No's 376, 423, 462, 472 and 478; a range of rootstocks potentially capable of producing very dwarf, moderately vigorous and vigorous trees. The results so far indicate that the trees on E.M. No. IX are very dwarfing; those on E.M. No's I and II are semi-vigorous growers, while those on E.M. No's X, XII, XIII and Crab C are quite vigorous. O-462 and O-472 are particularly promising as hardy stocks for McIntosh.

DOUBLE-WORKING

One of the major problems confronting the apple grower in Eastern Ontario, Quebec and New Brunswick is winter injury. It is not uncommon in these fruit districts to lose thousands of McIntosh trees simply because the trunk or crotch injury in the region where the main scaffold branches join the trunk is so severe that the trees are injured beyond repair. The records at the Horticultural Division, Ottawa, back to 1890, as well as those from other regions in Canada where severe winter conditions prevail disclose one very important fact, namely, that certain hardy Russian varieties, Hibernal, Charlamoff, Antonovka and Anis, can be grown year after year without loss from trunk injury, crotch injury, bark splitting, sunscald or any of the ailments to which even a good variety like McIntosh is subject. Observational data at Ottawa, (1, 2, 3, 4) and vicinity show that the commercial varieties, if they themselves are reasonably hardy, when topworked on the framework branches of these hardy Russian varieties, a practice known as "double-working", are highly resistant to the severe forms of winter injury; and moreover, that double-worked trees have a greater longevity than the single worked and are more uniform in performance and more productive. On the basis of these findings, the Horticultural Division, at present, is recommending as hardy stem builders, Hibernal, Antonovka and Virginia Crab, varieties which have been used commercially for some considerable time that fulfill the requirements of a variety for double-working. The above-mentioned varieties are not only resistant to winter injury but also to disease and insect pests, and are congenial with the commercial varieties grown in Eastern Canada. In the light of the present information, it is evident that the winter injury problems in Eastern Ontario, Quebec and New Brunswick may be almost entirely eliminated by the use of the recommended stem builders.

Comprehensive tree building trials have been set out by the Horticultural Division, in the past four years, at the Central Experimental Farm, Ottawa; Kemptville Agricultural School, Kemptville, Ontario; Experimental Station, Cap Rouge, Quebec; and on privately owned farms at Maitland, Ontario; Abbotsford, Quebec; Hemmingford, Quebec; Covey Hill, Quebec; Franklin Centre, Quebec. A large number of hardy varieties are being tested as stem builders in these orchards, under varying soil and climatic conditions, namely, Anis, Antonovka, Charlamoff, Columbia, Hardy Crab from Byshe, Hibernal, Osman, Patten Greening, *Malus baccata*, McMahon White, Robin, Rosthern Sdlg. No. 16, Virginia Crab and several Ottawa numbered hybrid varieties. In these experiments the promising new commercial varieties have been employed as fruiting varieties in an endeavour to obtain some fundamental information on their performance when top-worked on the above hardy stem builders. So far, (9) Charlamoff and Hibernal are the most vigorous of the intermediate varieties under investigation. Hibernal because of its strong right-angled branching system, free of bark inclusions, capable of withstanding heavy loads of fruit without breaking down at the crotches is preferable to Charlamoff. The growth rate of Niobe (Northern Spy seedling originated at Ottawa) double worked trees with interpolated intermediate stem pieces 4 inches long of E.M. No. IX is significantly lower than single worked trees on the same seedling rootstocks. The double worked trees also bore a few fruits the third year after planting while single worked show no signs of fruiting as yet and are quite vegetative. The insertion of a semi-vigorous intermediate stem piece between a hardy vigorous stock and a free growing scion variety, particularly a late bearing variety, may provide a means of developing semi-vigorous commercial trees in Canada.

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BOOK REVIEW

THE BOTANY OF CROP PLANTS. J. M. Hector. Introduction to the Botany of Field Crops. Vol. I. Cereals. pp. i-xii, 1-478, xiii-xxxiv. Vol. II. Non-Cereals. pp. i-viii, 479-1127, ix-xxxiii. Central News Agency Ltd., Johannesburg, South Africa. £3.10.0 net per set.

These volumes fill a definite need for a comprehensive treatise on the fundamental botanical characters and affinities of common field crops. The average specialized agricultural worker in America, whether he is geneticist, physiologist, pathologist or agronomist is woefully ignorant of the basic botanical facts relating to the plants with which he deals. This is in some measure a reflection on the training provided by many agricultural schools. Books such as the present one by J. M. Hector, who is Professor of Agricultural Botany in the University of Pretoria, should do much towards ameliorating this situation.

Hector defines field crops "inclusively to incorporate all plants cultivated in the 'field', i.e., on arable land; exclusively to omit the plants of the garden, the orchard, the grove and the plantation." He includes 22 major groups made up of a great many species. Although the work comes from South Africa its usefulness is by no means limited to that country; most if not all Canadian field crops are included along with a number of crops which require a warmer climate.

A chapter is devoted to each important botanical group e.g., oat species, wheat species, legumes. Under each group a more or less definite order of treatment is followed. First the morphology of roots, stem, leaves, inflorescence, flowers and fruit is discussed. The cytogenetics of the group, especially the chromosome numbers and morphology and their relation to the origin of the cultivated forms is fully set forth. The details of germination and seedling anatomy are also included. Perhaps one of the most valuable features of the book is the adequate discussion of the classification of the various groups. Cultivated plants are frequently most difficult to identify because the taxonomic literature concerning them is widely scattered or non-existent. Hector presents detailed keys to the cultivated species and botanical varieties, along with their closely related wild congeners. Following the keys come descriptions of these forms and notes on their geographic distribution. Considerable place is given to discussions of hybridization within the various groups. Due to the method of treating individual groups the physiological aspects of the subject are dealt with incidentally but in many chapters, especially that on cotton, many important physiological data are presented. Each chapter concludes with a comprehensive bibliography including the literature to the end of 1935. Some three thousand references are included in all.

The first volume deals with the cereals: oat species; millets; sugar canes; sorghums; and maize or Indian corn. The cytogenetic sections on wheat and Indian corn will be found to be especially valuable summaries.

In volume two a wide variety of crops is discussed: Liliaceae (onions, asparagus); Moraceae (hemp, hops); Polygonaceae (buckwheat, rhubarb);

Chenopodiaceae (beets, mangolds, spinach); Cruciferae (cabbage, rape, turnips, swedes, mustard, radishes); Leguminosae (peas, beans, vetches, peanuts, soy beans, alfalfa, sweet clover, clovers); Linaceae (flax); Malvaceae (cotton); Umbelliferae (carrot, parsnip, celery); Convolvulaceae (sweet potato); Solanaceae (potato, eggplant, tomato, tobacco); Cucurbitaceae (pumpkin, squash, cucumber); Compositae (chicory, endive, lettuce, sunflower, Jerusalem artichoke). Outstanding in this volume are the sections dealing with the legumes, cotton, and the potato. The presentation of the information on the potato is an able synthesis of fascinating studies in the fields of plant geography, ethnobotany, cytology, plant physiology, histology, and their contributions to the breeding of better potatoes. The author has drawn on the botanical literature of the whole world for his information and it is especially gratifying to find the most important Russian and Japanese work included.

The work is well printed on a good quality paper but unfortunately the binding is not as sturdy as is desirable in a reference work of this kind. There are over four hundred illustrations, drawn chiefly from the original papers. Where these are line drawings reproduced as zinc etchings they are well done but where half tones are included the quality of the work is poor and in some instances definition is entirely lacking. There is in each volume an author index, a plant index, and a general index so that the information is quickly available.

Notwithstanding the minor faults of insecure binding and faulty reproduction this work should definitely be a landmark in agricultural botany. It should find a place on the reference shelf of every agricultural research institution. Every agricultural college and university should use it extensively in the teaching of general as well as agricultural botany; it will inform and stimulate student and teacher alike.

HAROLD A. SENN.